BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (PQRS)

CALORIMETRY & HEAT TRANSFER

CONTENTS

THERMAL EXPANSION

Definition of Heat :

Heat is a form of energy which is transferred between a system and its surrounding as a result of temperature difference only.

Thermal Expansion : Expansion due to increase in temperature.

1. Type of thermal expansion

	Coefficient of expansion	**For temperature change Δt change in**
(i) Linear	$\alpha = \lim\limits_{\Delta t \to 0} \frac{1}{l_0}\frac{\Delta l}{\Delta t}$	length $\Delta l = l_0\,\alpha\,\Delta t$
(ii) Superficial	$\beta = \lim\limits_{\Delta t \to 0} \frac{1}{A_0}\frac{\Delta A}{\Delta t}$	Area $\Delta A = A_0\beta\Delta t$
(iii) Volume	$\gamma = \lim\limits_{\Delta t \to 0} \frac{1}{V_0}\frac{\Delta V}{\Delta t}$	volume $\Delta V = V_0\gamma\Delta t$

(a) For isotropic solids $\alpha_1 = \alpha_2 = \alpha_3 = \alpha$ (let)
so $\beta = 2\alpha$ and $\gamma = 3\alpha$

(b) For anisotropic solids $\beta = \alpha_1 + \alpha_2$ and $\gamma = \alpha_1 + \alpha_2 + \alpha_3$
Here α_1, α_2 and α_3 are coefficient of linear expansion in X, Y and Z directions.

2. Variation in density : With increase of temperature volume increases so density decreases and vice-versa.

$$d = \frac{d_0}{(1+\gamma\Delta t)}$$

For solids values of γ are generally small so we can write $d = d_0\,(1-\gamma\Delta t)$ (using bimomial expansion)

Note :

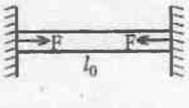
(i) γ for liquids are in order of 10^{-3}

(ii) For water density increases from 0 to 4°C so γ is –ve (0 to 4° C) and for 4° C to higher temperature γ is +ve. At 4° C density is maximum.

3. Thermal Stress : A rod of length l_0 is clamped between two fixed walls with distance l_0. If temperature is changed by amount Δt then

$$\text{stress} = \frac{F}{A} \quad \text{(area assumed to be constant)}$$

$$\text{strain} = \frac{\Delta l}{l_0}$$



so, $$Y = \frac{F/A}{\Delta l/l_0} = \frac{Fl_0}{A\Delta l} = \frac{F}{A\alpha\Delta t}$$

or $$F = YA\alpha\Delta t$$

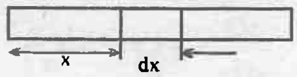
4. ***If α is not constant***

(i) (α varies with distance) Let $\alpha = ax+b$

Total expansion = $\int \textit{expansion of length } dx = \int_0^l (ax+b)dx\,\Delta t$

(ii) (α varies with tempearture)

Let $\alpha = f(T)$



$$\Delta l = \int_{T_1}^{T_2} \alpha l_0 \, dT$$

Caution : If α is in °C then put T_1 and T_2 in °C.
similarly if α is in K then put T_1 and T_2 in K.

CALORIMETRY

Quantity of heat transfered and specific heat

The amount of heat needed to incerase the temperature of 1 gm of water from 14.5° C to 15.5°C at STP is 1 calorie

$dQ = mcdT$

$$Q = m\int_{T_1}^{T_2} C\,dT$$ (be careful about unit of temperature, use units according to the given units of C)

Heat transfer in phase change

$Q = mL$ L = latent heat of substance in cal/ gm/ °C or in Kcal/ kg/ °C
L_{ice} = 80 cal/ gm for ice
L_{steam} = 540 cal/ gm

HEAT - TRANSFER

(A) ***Conduction :*** Due to vibration and collision of medium particles.

(i) ***Steady State :*** In this state heat absorption stops and temperature gradient throughout the rod becomes constant i.e. $\frac{dT}{dx}$ = constant.

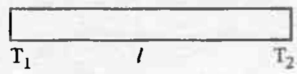
(ii) ***Before steady state :*** Temp of rod at any point changes

Note : If specific heat of any substance is zero, it can be considered always in steady state.

1. ***Ohm's law for Thermal Conduction in Steady State :***

Let the two ends of rod of length l is maintained at temp T_1 and T_2($T_1 > T_2$)

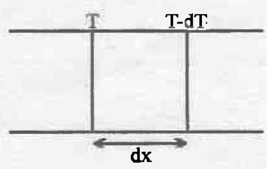
Thermal current $\frac{dQ}{dT} = \frac{T_1 - T_2}{K_{Th}}$



Where thermal resistance $R_{Th} = \frac{l}{KA}$

2. ***Differential form of Ohm's Law***

$\frac{dQ}{dT} = KA\frac{dT}{dx}$ $\frac{dT}{dx}$ = temperature gradient



(B) ***Convection :*** Heat transfer due to movement of medium particles.

(C) ***Radiation:*** Every body radiates electromagnetic radiation of all possible wavelength at all temp>0 K.

1. ***Stefan's Law :*** Rate of heat emitted by a body at temp T K from per unit area $E = \sigma T^4$ J/sec/m^2

Radiation power $\frac{dQ}{dT} = P = \sigma A T^4$ watt

If a body is placed in a surrounding of temperature T_S

$$\frac{dQ}{dT} = \sigma A(T^4 - T_s^4)$$

valid only for black body

Emissivity or emmisive power $e = \frac{\text{heat from general body}}{\text{heat from black body}}$

If temp of body falls by dT in time dt

$$\frac{dT}{dt} = \frac{eA\sigma}{mS}(T^4 - T_s^4) \qquad (dT/dt = \text{rate of cooling})$$

2. ***Newton's law of cooling***

If temp difference of body with surrounding is small i.e. $T = T_s$

then, $$\frac{dT}{dt} = \frac{4eA\sigma}{mS}T_s^3(T - T_s)$$

so $$\frac{dT}{dt} \propto (T - T_s)$$

3. ***Average form of Newtons law of cooling***

If a body cools from T_1 to T_2 in time δt

$$\frac{T_1 - T_2}{\delta t} = \frac{K}{mS}\left(\frac{T_1 + T_2}{2} - T_s\right) \quad \text{(used generally in objective questions)}$$

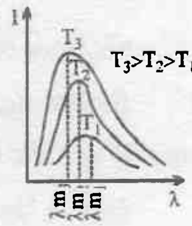
$$\frac{dT}{dt} = \frac{K}{mS}(T - T_s) \quad \text{(for better results use this generally in subjective)}$$

4. ***Wein's black body radiation***

At every temperature (>0K) a body radiates energy radiations of all wavelengths. According to Wein's displacement law if the wavelength corresponding to maximum energy is λ_m

then $\lambda_m T = b$ where b = is a constant (Wein's constant)

T = temperature of body



EXERCISE – I

Q.1 An aluminium container of mass 100 gm contains 200 gm of ice at – 20°C. Heat is added to the system at the rate of 100 cal/s. Find the temperature of the system after 4 minutes (specific heat of ice = 0.5 and L = 80 cal/gm, specific heat of A*l* = 0.2 cal/gm/°C)

Q.2 A U-tube filled with a liquid of volumetric coefficient of 10^{-5}/°C lies in a vertical plane. The height of liquid column in the left vertical limb is 100 cm. The liquid in the left vertical limb is maintained at a temperature = 0°C while the liquid in the right limb is maintained at a temperature = 100°C. Find the difference in levels in the two limbs.

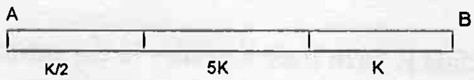
Q.3 A thin walled metal tank of surface area 5m^2 is filled with water tank and contains an immersion heater dissipating 1 kW. The tank is covered with 4 cm thick layer of insulation whose thermal conductivity is 0.2 W/m/K. The outer face of the insulation is 25°C. Find the temperature of the tank in the steady state

Q.4 A glass flask contains some mercury at room temperature. It is found that at different temperatures the volume of air inside the flask remains the same. If the volume of mercury in the flask is 300 cm^3, then find volume of the flask (given that coefficient of volume expansion of mercury and coefficient of linear expansion of glass are 1.8×10^{-4} (°C)$^{-1}$ and 9×10^{-6} (°C)$^{-1}$ respectively)

Q.5 A clock pendulum made of invar has a period of 0.5 sec at 20°C. If the clock is used in a climate where average temperature is 30°C, aporoximately. How much fast or slow will the clock run in 10^6 sec. ($\alpha_{invar} = 1 \times 10^{-6}$/°C)

Q.6 A pan filled with hot food cools from 50.1 °C to 49.9 °C in 5 sec. How long will it take to cool from 40.1 °C to 39.9°C if room temperature is 30°C?

Q.7 A composite rod made of three rods of equal length and cross-section as shown in the fig. The thermal conductivities of the materials of the rods are K/2, 5K and K respectively. The end A and end B are at constant temperatures. All heat entering the face A goes out of the end B there being no loss of heat from the sides of the bar. Find the effective thermal conductivity of the bar

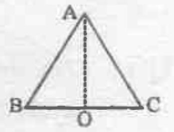


Q.8 An iron bar (Young's modulus = 10^{11} N/m^2 , $\alpha = 10^{-6}$ /°C) 1 m long and 10^{-3} m^2 in area is heated from 0°C to 100°C without being allowed to bend or expand. Find the compressive force developed inside the bar.

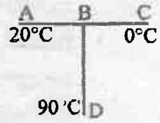
Q.9 A solid copper cube and sphere, both of same mass & emissivity are heated to same initial temperature and kept under identical conditions. What is the ratio of their initial rate of fall of temperature?

Q.10 A cylindrical rod with one end in a stream chamber and other end in ice cause melting of 0.1 gm of ice/sec. If the rod is replaced with another rod of half the length and double the radius of first and thermal conductivity of second rod is 1/4 that of first, find the rate of ice melting in gm/sec

Q.11 Three aluminium rods of equal length form an equilateral triangle ABC. Taking O (mid point of rod BC) as the origin. Find the increase in Y-coordinate per unit change in temperature of the centre of mass of the system. Assume the length of the each rod is 2m, and $\alpha_{al} = 4\sqrt{3}\times10^{-6}\ /°C$



Q.12 Three conducting rods of same material and cross-section are shown in figure. Temperature of A, D and C are maintained at 20°C, 90°C and 0°C. Find the ratio of length BD and BC if there is no heat flow in AB

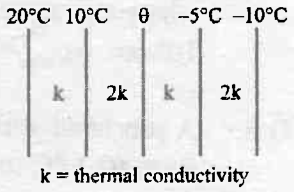


Q.13 If two rods of layer L and 2 L having coefficients of linear expansion α and 2α respectively are connected so that total length becomes 3 L, determine the average coefficient of linear expansion of the composite rod.

Q.14 A volume of 120 ml of drink (half alcohol + half water by mass) originally at a temperature of 25°C is cooled by adding 20 gm ice at 0°C. If all the ice melts, find the final temperature of the drink. (density of drink = 0.833 gm/cc, specific heat of alcohol = 0.6 cal/gm/°C)

Q.15 A solid receives heat by radiation over its surface at the rate of 4 kW. The heat convection rate from the surface of solid to the surrounding is 5.2 kW, and heat is generated at a rate of 1.7 kW over the volume of the solid. The rate of change of the average temperature of the solid is $0.5°Cs^{-1}$. Find the heat capacity of the solid.

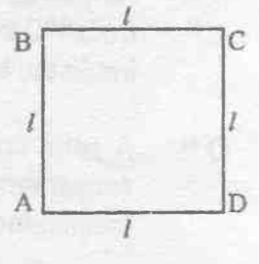
Q.16 The figure shows the face and interface temperature of a composite slab containing of four layers of two materials having identical thickness. Under steady state condition, find the value of temperature θ.



Q.17 Two identical calorimeter A and B contain equal quantity of water at 20°C. A 5 gm piece of metal X of specific heat 0.2 cal g^{-1} $(C°)^{-1}$ is dropped into A and a 5 gm piece of metal Y into B. The equilibrium temperature in A is 22°C and in B 23°C. The initial temperature of both the metals is 40°C. Find the specific heat of metal Y in cal g^{-1} $(C°)^{-1}$.

Q.18 Two spheres of same radius R have their densities in the ration 8 . 1 and the ratio of their specifi heats are 1 : 4. If by radiation their rates of fall of temperature are same, then find the ratio of their rates of losing heat.

Q.19 In the square frame of side l of metallic rods, the corners A and C are maintained at T_1 and T_2 respectively. The rate of heat flow from A to C is ω. If A and D are instead maintained T_1 & T_2 respectivley find, find the total rate of heat flow.



Q.20 A hot liquid contained in a container of negligible heat capacity loses temperature at rate 3 K/min, just before it begins to solidify. The temperature remains constant for 30 min. Find the ratio of specific heat capacity of liquid to specific latent heat of fusion is in K^{-1} (given that rate of losing heat is constant).

Q.21 A thermostatted chamber at small height h above earth's surface maintained at 30°C has a clock fitted in it with an uncompensated pendulum. The clock designer correctly designs it for height h, but for temperature of 20°C. If this chamber is taken to earth's surface, the clock in it would click correct time. Find the coefficient of linear expansion of material of pendulum. (earth's radius is R)

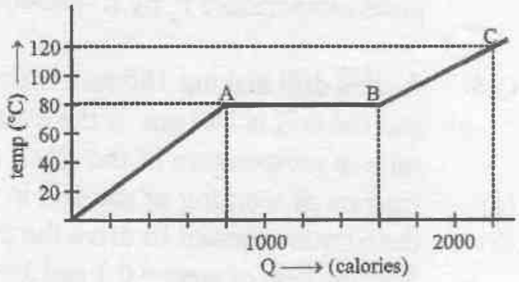
Q.22 The coefficient of volume expansion of mercury is 20 times the coefficient of linear expansion of glass. Find the volume of mercury that must be poured into a glass vessel of volume V so that the volume above mercury may remain constant at all temperature.

Q.23 Two 50 gm ice cubes are dropped into 250 gm of water ion a glass. If the water was initially at a temperature of 25°C and the temperature of ice –15°C. Find the final temperature of water. (specific heat of ice = 0.5 cal/gm/°C and L = 80 cal/gm)

Q.24 Water is heated from 10°C to 90°C in a residential hot water heater at a rate of 70 litre per minute. Natural gas with a density of 1.2 kg/m^3 is used in the heater, which has a transfer efficiency of 32%. Find the gas consumption rate in cubic meters per hour. (heat combustion for natural gas is 8400 kcal/kg)

Q.25 A metal rod A of 25cm lengths expands by 0.050cm. When its temperature is raised from 0°C to 100°C. Another rod B of a different metal of length 40cm expands by 0.040 cm for the same rise in temperature. A third rod C of 50cm length is made up of pieces of rods A and B placed end to end expands by 0.03 cm on heating from 0°C to 50°C. Find the lengths of each portion of the composite rod.

Q.26 A substance is in the solid form at 0°C. The amount of heat added to this substance and its temperature are plotted in the following graph. If the relative specific heat capacity of the solid substance is 0.5, find from the graph



(i) the mass of the substance ;
(ii) the specific latent heat of the melting process, and
(iii) the specific heat of the substance in the liquid state.

Q.27 One end of copper rod of uniform cross-section and of length 1.5 meters is in contact with melting ice and the other end with boiling water. At what point along its length should a temperature of 200°C be maintained, so that in steady state, the mass of ice melting is equal to that of steam produced in the same interval of time? Assume that the whole system is insulated from the surroundings.

Q.28 Two solids spheres are heated to the same temperature and allowed to cool under identical conditions. Compare: (i) initial rates of fall of temperature, and (ii) initial rates of loss of heat. Assume that all the surfaces have the same emissivity and ratios of their radii of, specific heats and densities are respectively $1 : \alpha$, $1 : \beta$, $1 : \gamma$.

Q.29 A vessel containing 100 gm water at 0°C is suspended in the middle of a room. In 15 minutes the temperature of the water rises by 2°C. When an equal amount of ice is placed in the vessel, it melts in 10 hours. Calculate the specific heat of fusion of ice.

Q.30 The maximum in the energy distribution spectrum of the sun is at 4753 Å and its temperature is 6050K. What will be the temperature of the star whose energy distribution shows a maximum at 9506 Å.

EXERCISE – II

Q.1 A copper calorimeter of mass 100 gm contains 200 gm of a mixture of ice and water. Steam at 100°C under normal pressure is passed into the calorimeter and the temperature of the mixture is allowed to rise to 50°C. If the mass of the calorimeter and its contents is now 330 gm, what was the ratio of ice and water in the beginning? Neglect heat losses.
Given : Specific heat capacity of copper = 0.42×10^3 J $kg^{-1}K^{-1}$,
Specific heat capacity of water = 4.2×10^3 J $kg^{-1}K^{-1}$,
Specific heat of fusion of ice = 3.36×10^5 J kg^{-1}
Latent heat of condensation of steam = 22.5×10^5 Jkg^{-1}

Q.2 An isosceles triangle is formed with a rod of length l_1 and coefficient of linear expansion α_1 for the base and two thin rods each of length l_2 and coefficient of linear expansion α_2 for the two pieces, if the distance between the apex and the midpoint of the base remain unchanged as the temperatures varied show that $\frac{l_1}{l_2} = 2\sqrt{\frac{\alpha_2}{\alpha_1}}$.

Q.3 A solid substance of mass 10 gm at – 10°C was heated to – 2°C (still in the solid state). The heat required was 64 calories. Another 880 calories was required to raise the temperature of the substance (now in the liquid state) to 1°C, while 900 calories was required to raise the temperature from –2°C to 3°C. Calculate the specific heat capacities of the substances in the solid and liquid state in calories per kilogram per kelvin. Show that the latent heat of fusion L is related to the melting point temperature t_m by $L = 85400 + 200\, t_m$.

Q.4 A steel drill making 180 rpm is used to drill a hole in a block of steel. The mass of the steel block and the drill is 180 gm. If the entire mechanical work is used up in producing heat and the rate of raise in temperature of the block and the drill is 0.5 °C/s. Find
(a) the rate of working of the drill in watts, and
(b) the torque required to drive the drill.
Specific heat of steel = 0.1 and J = 4.2 J/cal. Use : $P = \tau\, \omega$

Q.5 A brass rod of mass m = 4.25 kg and a cross sectional area 5 cm^2 increases its length by 0.3 mm upon heating from 0°C. What amount of heat is spent for heating the rod? The coefficient of linear expansion for brass is 2×10^{-5}/K, its specific heat is 0.39 kJ/kg.K and the density of brass is 8.5×10^3 kg/m^3.

Q.6 A submarine made of steel weighing 10^9 g has to take 10^8 g of water in order to submerge when the temperature of the sea is 10°C. How much less water it will have to take in when the sea is at 15°C? (Coefficient of cubic expansion of sea water = 2×10^{-4}/°C, coefficient of linear expansion of steel = 1.2×10^{-5}/°C)

Q.7 A flow calorimeter is used to measure the specific heat of a liquid. Heat is added at a known rate to a stream of the liquid as it passes through the calorimeter at a known rate. Then a measurement of the resulting temperature difference between the inflow and the outflow points of the liquid stream enables us to compute the specific heat of the liquid. A liquid of density 0.2 g/cm^3 flows through a calorimeter at the rate of 10 cm^3/s. Heat is added by means of a 250-W electric heating coil, and a temperature difference of 25°C is established in steady-state conditions between the inflow and the outflow points. Find the specific heat of the liquid.

Q.8 Toluene liquid of volume 300 cm³ at 0°C is contained in a beaker an another quantity of toluene of volume 110 cm³ at 100°C is in another beaker. (The combined volume is 410 cm³). Determine the total volume of the mixture of the toluene liquids when they are mixed together. Given the coefficient of volume expansion $\gamma = 0.001/C$ and all forms of heat losses can be ignored. Also find the final temperature of the mixture.

Q.9 Ice at -20°C is filled upto height h = 10 cm in a uniform cylindrical vessel. Water at temperature θ°C is filled in another identical vessel upto the same height h= 10 cm. Now, water from second vessel is poured into first vessel and it is found that level of upper surface falls through $\Delta h = 0.5$ cm when thermal equilibrium is reached. Neglecting thermal capacity of vessels, change in density of water due to change in temperature and loss of heat due to radiation, calculate initial temperature θ of water.

Given, Density of water, $\rho_w = 1$ gm cm^{-3}
Density of ice, $\rho_i = 0.9$ gm/cm³
Specific heat of water, $s_w = 1$ cal/gm °C
Specific heat of ice, $s_i = 0.5$ cal/gm°C
Specific latent heat of ice, L = 80 cal/gm

Q.10 A composite body consists of two rectangular plates of the same dimensions but different thermal conductivities K_A and K_B. This body is used to transfer heat between two objects maintained at different temperatures. The composite body can be placed such that flow of heat takes place either parallel to the interface or perpendicular to it. Calculate the effective thermal conductivities $K_{\parallel}$ and $K_{\perp}$ of the composite body for the parallel and perpendicular orientations. Which orientation will have more thermal conductivity?

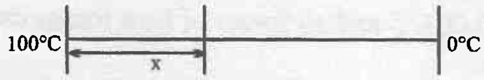
Q.11 Two identical thermally insulated vessels, each containing n mole of an ideal monatomic gas, are interconnected by a rod of length l and cross-sectional area A. Material of the rod has thermal conductivity K and its lateral surface is thermally insulated. If, at initial moment (t = 0), temperature of gas in two vessels is T_1 and T_2 ($< T_1$), neglecting thermal capacity of the rod, calculate difference between temperature of gas in two vessels as a function of time.

Q.12 A highly conducting solid cylinder of radius a and length l is surrounded by a co-axial layer of a material having thermal conductivity K and negligible heat capacity. Temperature of surrounding space (out side the layer) is T_0, which is higher than temperature of the cylinder. If heat capacity per unit volume of cylinder material is s and outer radius of the layer is b, calculate time required to increase temperature of the cylinder from T_1 to T_2. Assume end faces to be thermally insulated.

Q.13 A vertical brick duct(tube) is filled with cast iron. The lower end of the duct is maintained at a temperature T_1 which is greater than the melting point T_m of cast iron and the upper end at a temperature T_2 which is less than the temperature of the melting point of cast iron. It is given that the conductivity of liquid cast iron is equal to k times the conductivity of solid cast iron. Determine the fraction of the duct filled with molten metal.

Q.14 Water is filled in a non-conducting cylindrical vessel of uniform cross-sectional area. Height of water column is h_0 and temperature is 0°C. If the vessel is exposed to an atmosphere having constant temperature of $-\theta$°C (< 0°C) at t = 0, calculate total height h of the column at time t. Assume thermal conductivity of ice to be equal to K. Density of water is ρ_ω and that of ice is ρ_i. Latent heat of fusion of ice is L.

Q.15 A lagged stick of cross section area 1 cm^2 and length 1 m is initially at a temperature of 0°C. It is then kept between 2 reservoirs of tempeature 100°C and 0°C. Specific heat capacity is 10 J/kg°C and linear mass density is 2 kg/m. Find



(a) temperature gradient along the rod in steady state.
(b) total heat absorbed by the rod to reach steady state.

Q.16 A cylindrical block of length 0.4 m an area of cross-section 0.04m^2 is placed coaxially on a thin metal disc of mass 0.4 kg and of the same cross-section. The upper face of the cylinder is maintained at a constant temperature of 400K and the initial temperature of the disc is 300K. If the thermal conductivity of the material of the cylinder is 10 watt/m-K and the specific heat of the material of the disc in 600 J/kg-K, how long will it take for the temperature of the disc to increase to 350K? Assume, for purposes of calculation, the thermal conductivity of the disc to be very high and the system to be thermally insulated except for the upper face of the cylinder.

Q.17 A copper calorimeter of negligible thermal capacity is filled with a liquid. The mass of the liquid equals 250 gm. A heating element of negligible thermal capacity is immersed in the liquid. It is found that the temperature of the calorimeter and its contents rises from 25°C to 30°C in 5 minutes when a current of 20.5 ampere is passed through it at potential difference of 5 volts. The liquid is thrown off and the heater is again switched on. It is now found that the temperature of the calorimeter alone is constantly maintained at 32°C when the current through the heater is 7A at the potential difference 6 volts. Calculate the specific heat capacity of the liquid. The temperature of the surroundings is 25°C.

Q.18 A solid copper sphere cools at the rate of 2.8°C per minute, when its temperature is 127°C. Find the rate at which another solid copper sphere of twice the radius lose its temperature at 327°C, if in both the cases, the room temperature is maintained at 27°C.

Q.19 A calorimeter contains 100 cm^3 of a liquid of density 0.88 g/cm^3 in which are immersed a thermometer and a small heating coil. The effective water equivalent of calorimeter, thermometer and heater may be taken to be 13 gm. Current of 2 A is passed through the coil. The potential difference across the coil is 6.3 V and the ultimate steady state temperature is 55°C. The current is increased so that the temperature rises slightly above 55°C, and then it is switched off. The calorimeter and the content are found to cool at the rate of 3.6°C/min.
(a) Find the specific heat of the liquid.
(b) The room temperature during the experiment was 10°C. If the room temperature rises to 26°C, find the current required to keep the liquid at 55°C. You may assume that Newton's law is obeyed and the resistance of the heater remains constant.

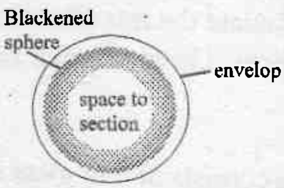
Q.20 End A of a rod AB of length L = 0.5 m and of uniform cross-sectional area is maintained at some constant temperature. The heat conductivity of the rod is k = 17 J/s-m°K. The other end B of this rod is radiating energy into vacuum and the wavelength with maximum energy density emitted from this end is λ_0 = 75000 Å. If the emissivity of the end B is e = 1, determine the temperature of the end A. Assuming that except the ends, the rod is thermally insulated.

Q.21 A wire of length 1.0 m and radius 10^{-3} m is carrying a heavy current and is assumed to radiate as a blackbody. At equilibrium temperature of wire is 900 K while that of the surroundings is 300 K. The resistivity of the material of the wire at 300 K is $\pi^2 \times 10^{-8}$ Ω-m and its temperature coefficient of resistance is 7.8×10^{-3} /°C. Find the current in the wire. [$\sigma \approxeq 5.68 \times 10^{-8}$ w/m^2K^4].

Q.22 The temperature distribution of solar radiation is more or less same as that of a black body whose maximum emission corresponds to the wavelength 0.483 μm. Find the rate of change of mass due to radiation. [Radius of Sun = 7.0×10^8 m]

Q.23 A black plane surface at a constant high temperature T_h, is parallel to another black plane surface at constant lower temperature T_l. Between the plates is vacuum. In order to reduce the heat flow due to radiation, a heat shield consisting of two thin black plates, thermally isolated from each other, it placed between the warm and the cold surfaces and parallel to these. After some time stationary conditions are obtained. By what factor η is the stationary heat flow reduced due to the presence of the heat shield? Neglect end effects due to the finite size of the surfaces.

Q.24 The shell of a space station is a blackened sphere in which a temperature T = 500K is maintained due to operation of appliances of the station. Find the temperature of the shell if the station is enveloped by a thin spherical black screen of nearly the same radius as the radius of the shell.



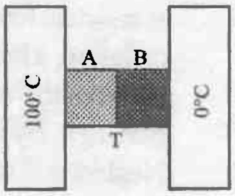
Q.25 A liquid takes 5 minutes to cool from 80°C to 50°C. How much time will it take to cool from 60°C to 30°C ? The temperature of surrounding is 20°C. Use exact method.

Q.26 Find the temperature of equilibrium of a perfectly black disc exposed normally to the Sun's ray on the surface of Earth. Imagine that it has a nonconducting backing so that it can radiate only to hemisphere of space. Assume temperature of surface of Sun = 6200 K, radius of sun = 6.9×10^8 m, distance between the Sun and the Earth = 1.5×10^{11} m. Stefan's constant = 5.7×10^{-8} W/m^2.K^4. What will be the temperature if both sides of the disc are radiate?

EXERCISE – III

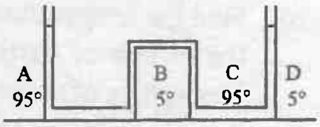
Q.1 The temperature of 100 gm of water is to be raised from 24° C to 90° C by adding steam to it. Calculate the mass of the steam required for this purpose. [JEE '96]

Q.2 Two metal cubes A & B of same size are arranged as shown in figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A & B are 300 W/m° C and 200 W/m° C respectively. After steady state is reached the temperature T of the interface will be ______. [JEE' 96]



Q.3 A double pane window used for insulating a room thermally from outside consists of two glass sheets each of area 1 m^2 and thickness 0.01 m separated by a 0.05m thick stagnant air space. In the steady state, the room glass interface and the glass outdoor interface are at constant temperatures of 27°C and 0°C respectively. Calculate the rate of heat flow through the window pane. Also find the temperatures of other interfaces. Given thermal conductivities of glass and air as 0.8 and 0.08 W $m^{-1}K^{-1}$ respectively. [JEE'97]

Q.4 The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 49 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95° C while the columns B & D are maintained at 5° C. The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. Determine the coefficient of thermal expansion of the liquid. [JEE '97]



Q.5 A spherical black body with a radius of 12 cm radiates 450 W power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be :
(A) 225 (B) 450 (C) 900 (D) 1800

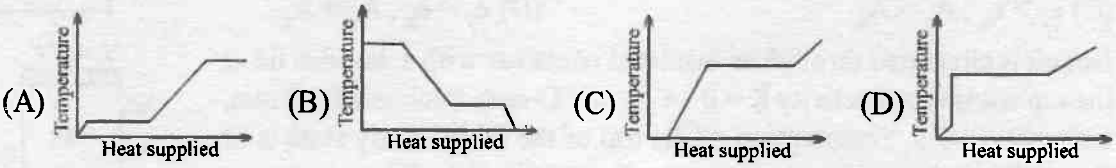
Q.6 Earth receives 1400 W/m^2 of solar power. If all the solar energy falling on a lens of area 0.2 m^2 is focussed on to a block of ice of mass 280 grams, the time taken to melt the ice will be ______ minutes. (Latent heat of fusion of ice = 3.3 x 10^5 J/kg) [JEE '97]

Q.7 A solid body X of heat capacity C is kept in an atmosphere whose temperature is T_A = 300K. At time t = 0, the temperature of X is T_0 = 400K. It cools according to Newton's law of cooling. At time t_1 its temperature is found to be 350K. At this time t_1, the body X is connected to a larger body Y at atmospheric temperature T_A, through a conducting rod of length L, cross-sectional area A and thermal conductivity K. The heat capacity of Y is so large that any variation in its temperature may be neglected. The cross-sectional area A of the connecting rod is small compared to the surface area of X. Find the temperature of X at time t = $3t_1$. [JEE' 98]

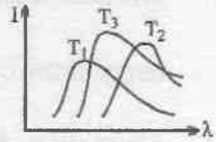
Q.8 A black body is at a temperature of 2880 K. The energy of radiation emitted by this object with wavelength between 499 nm and 500 nm is U_1, between 999 nm and 1000 nm is U_2 and between 1499 nm and 1500 nm is U_3. The Wien constant b = 2.88 × 10^6 nm K. Then [JEE' 98]
(A) $U_1 = 0$ (B) $U_3 = 0$ (C) $U_1 > U_2$ (D) $U_2 > U_1$

Q.9 A bimetallic strip is formed out of two identical strips one of copper and the other of brass. The coefficient of linear expansion of the two metals are α_C and α_B. On heating, the temperature of the strip goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is :
(A) proportional at ΔT
(B) inversely proportional to ΔT [JEE' 99]
(C) proportional to $|\alpha_B - \alpha_C|$
(D) inversely proportional to $|\alpha_B - \alpha_C|$

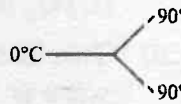
Q.10 A block of ice at – 10°C is slowly heated and converted to steam at 100°C. Which of the following curves represents the phenomenon qualitatively? [JEE (Scr) 2000]



Q.11 The plots of intensity versus wavelength for three black bodies at temperature T_1 , T_2 and T_3 respectively are as shown. Then temperatures are such that [JEE (Scr) 2000]
(A) $T_1 > T_2 > T_3$
(B) $T_1 > T_3 > T_2$
(C) $T_2 > T_3 > T_1$
(C) $T_3 > T_2 > T_1$



Q.12 Three rods made of the same material and having the same cross-section have been joined as shown in the figure. Each rod is of the same length. The left and right ends are kept at 0°C and 90°C respectively. The temperature of the junction of the three rods will be [JEE(Scr)2001]
(A) 45°C
(B) 60°C
(C) 30°C
(D) 20°C



Q.13 An ideal black body at room temperature is thrown into a furnace. It is observed that
(A) initially it is the darkest body and at later times the brightest.
(B) it the darkest body at all times
(C) it cannot be distinguished at all times.
(D) initially it is the darkest body and at later times it cannot be distinguished. [JEE(Scr)2002]

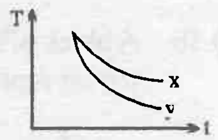
Q.14 An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat S of the container varies with temperature T according the empirical relations = A + BT, where A = 100 cal/kg-K and B = 2×10^{-2} cal/kg-K^2. If the final temperature of the container is 27°C, determine the mass of the container. (Latent heat of fusion for water = 8×10^4 cal/kg. Specific heat of water = 10^3 cal/kg-K) [JEE' 2001]

Q.15 Two rods one of aluminium of length l_1 having coefficient of linear expansion α_a, and other steel of length l_2 having coefficient of linear expansion α_s are joined end to end. The expansion in both the rods is same on variation of temperature. Then the value of $\frac{l_1}{l_1 + l_2}$ is [JEE' (Scr) 2003]

(A) $\frac{\alpha_s}{\alpha_a + \alpha_s}$
(B) $\frac{\alpha_s}{\alpha_a - \alpha_s}$
(C) $\frac{\alpha_a + \alpha_s}{\alpha_s}$
(D) None of these

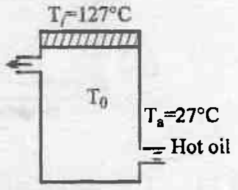
Q.16 2 kg ice at – 20°C is mixed with 5 kg water at 20°C. Then final amount of water in the mixture would be; Given specific heat of ice = 0.5cal/g°C, specific heat of water = 1 cal/g°C, Latent heat of fusion of ice = 80 cal/g. [JEE' (Scr) 2003]
(A) 6 kg (B) 5 kg (C) 4 kg (D) 2 kg

Q.17 If emissivity of bodies X and Y are e_x and e_y and absorptive power are A_x and A_y then [JEE' (Scr) 2003]



(A) $e_y > e_x$; $A_y > A_x$
(B) $e_y < e_x$; $A_y < A_x$
(C) $e_y > e_x$; $A_y < A_x$
(D) $e_y = e_x$; $A_y = A_x$

Q.18 Hot oil is circulated through an insulated container with a wooden lid at the top whose conductivity K = 0.149 J/(m-°C-sec), thickness t = 5 mm, emissivity = 0.6. Temperature of the top of the lid in steady state is at T_l = 127°. If the ambient temperature T_a = 27°C. Calculate



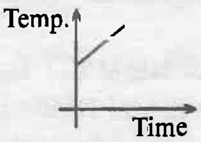
(a) rate of heat loss per unit area due to radiation from the lid.

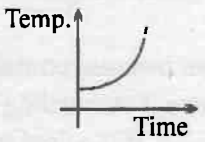
(b) temperature of the oil. (Given $\sigma = \frac{17}{3} \times 10^{-8}$) [JEE' 2003]

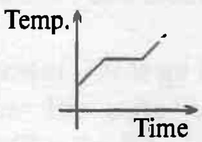
Q.19 Three discs A, B, and C having radii 2 m, 4 m and 6 m respectively are coated with carbon black on their outer surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm respectively. The power radiated by them are Q_A, Q_B and Q_C respectively.
(a) Q_A is maximum (B) Q_B is maximum [JEE' 2004 (Scr.)]
(C) Q_C is maximum (D) $Q_A = Q_B = Q_C$

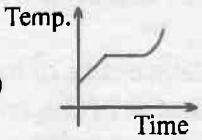
Q.20 Two identical conducting rods are first connected independently to two vessels, one containing water at 100°C and the other containing ice at 0° C. In the second case, the rods are joined end to end and connected to the same vessels. Let q_1 and q_2 g/s be the rate of melting of ice in the two cases respectively. The ratio q_2/q_1 is
(A) 1/2 (B) 2/1 (C) 4/1 (D) 1/4 [JEE' 2004 (Scr.)]

Q.21 Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which of the following graphs represents the variation of temperature with time?

(A) 

(B) 

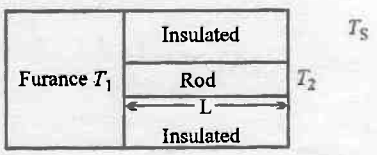
(C) 

(D) 

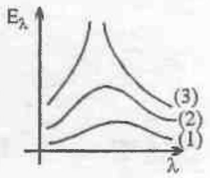
[JEE' 2004 (Scr.)]

Q.22 A cube of coefficient of linear expansion α_s is floating in a bath containing a liquid of coefficient of volume expansion γ_l. When the temperature is raised by ΔT, the depth upto which the cube is submerged in the liquid remains the same. Find the relation between α_s and γ_l, showing all the steps. [JEE 2004]

Q.23 One end of a rod of length L and cross-sectional area A is kept in a furnace of temperature T_1. The other end of the rod is kept at a temperature T_2. The thermal conductivity of the material of the rod is K and emissivity of the rod is e. It is given that $T_2 = T_S + \Delta T$ where $\Delta T << T_S$, T_S being the temperature of the surroundings. If $\Delta T \propto (T_1 - T_S)$, find the proportionality constant. Consider that heat is lost only by radiation at the end where the temperature of the rod is T_2. [JEE 2004]



Q.24 Three graphs marked as 1, 2, 3 representing the variation of maximum emissive power and wavelength of radiation of the sun, a welding arc and a tungsten filament. Which of the following combination is correct



(A) 1-bulb, 2 $\rightarrow$ welding arc, 3 $\rightarrow$ sun
(B) 2-bulb, 3 $\rightarrow$ welding arc, 1 $\rightarrow$ sun
(C) 3-bulb, 1 $\rightarrow$ welding arc, 2 $\rightarrow$ sun
(D) 2-bulb, 1 $\rightarrow$ welding arc, 3 $\rightarrow$ sun
[JEE' 2005 (Scr)]

Q.25 In which of the following phenomenon heat convection does not take place
(A) land and sea breeze
(B) boiling of water
(C) heating of glass surface due to filament of the bulb
(D) air around the furance
[JEE' 2005 (Scr)]

Q.26 2 litre water at 27°C is heated by a 1 kW heater in an open container. On an average heat is lost to surroundings at the rate 160 J/s. The time required for the temperature to reach 77°C is
(A) 8 min 20 sec (B) 10 min (C) 7 min (D) 14 min
[JEE' 2005 (Scr)]

Q.27 A spherical body of area A, and emissivity e = 0.6 is kept inside a black body. What is the rate at which energy is radiated per second at temperature T
(A) $0.6\,\sigma AT^4$ (B) $0.4\,\sigma AT^4$ (C) $0.8\,\sigma AT^4$ (D) $1.0\,\sigma AT^4$
[JEE' 2005 (Scr)]

Q.28 1 calorie is the heat required to increased the temperature of 1 gm of water by 1°C from
(A) 13.5°C to 14.5°C at 76 mm of Hg (B) 14.5°C to 15.5°C at 760 mm of Hg
(C) 0°C to 1°C at 760 mm of Hg (D) 3°C to 4°C to 760 mm of Hg
[JEE' 2005 (Scr)]

ANSWER KEY

EXERCISE –1

Q.1	25.5°C	Q.2	0.1 cm	Q.3	65°C	Q.4	2000 cm^3
Q.5	5 sec slow	Q.6	10 sec	Q.7	15K/16	Q.8	10, 000 N
Q.9	$\left(\frac{6}{\pi}\right)^{1/3}$	Q.10	0.2	Q.11	4×10^{-6} m/°C		
Q.12	7/2	Q.13	5α/3	Q.14	4°C	Q.15	1000 J (C°)$^{-1}$
Q.16	5°C	Q.17	27/85	Q.18	2 : 1	Q.19	(4/3) ω
Q.20	1/90	Q.21	h/5R	Q.22	3V / 20	Q.23	0 °C
Q.24	104.2	Q.25	10cm , 40cm	Q.26	(i)0.02kg,(ii) 40,000calkg^{-1},(iii)750calkg^{-1}K^{-1}		
Q.27	10.34 cm	Q.28	αβγ : 1 ; 1 : α^2	Q.29	80 k cal/kg	Q.30	3025 K

EXERCISE – II

Q.1 1 : 1.26 Q.3 800 cal kg^{-1} K^{-1}, 1000 cal kg^{-1} K^{-1}

Q.4 (a) 37.8 J/s (Watts), (b) 2.005 N-m Q.5 25 kJ Q.6 9.02×10^5 gm

Q.7 5000 J/°C kg Q.8 decrease by 0.75 cm^3, 25°C Q.9 45^{0}C

Q.10 $K_{\shortparallel} > K_{\perp}$, $K_{\parallel} = \frac{K_A + K_B}{2}$, $K_{\perp} = \frac{2K_AK_B}{K_A + K_B}$ Q.11 $(T_1 - T_2)e^{-\left(\frac{4KAt}{3nR\ell}\right)}$

Q.12 $\frac{a^2s}{2K}\log_e\left(\frac{b}{a}\right)\log_e\left(\frac{T_0 - T_1}{T_0 - T_2}\right)$ Q.13 $\frac{l_1}{l} = \frac{k(T_1 - T_m)}{k(T_1 - T_m) + (T_m - T_2)}$

Q.14 $h_0 + \left(1 - \frac{\rho_i}{\rho_w}\right)\sqrt{\frac{2k_i\theta t}{\rho_i L_f}}$ Q.15 (a) 100 °C/m, (b) 1000 J Q.16 166.3 sec

Q.17 21000 Jkg^{-1}K^{-1} Q.18 9.72^{0}C/min Q.19 (a)0.42 cal/gm°C, (b) 1.6A

Q.20 $T_A = 423$ K Q.21 36 A Q.22 $\frac{dm}{dt} = 5.06 \times 10^9$ kg/s

Q.23 $\eta = 3$ Q.24 $T'' = \sqrt[4]{2} \times 500 = 600$ K

Q.25 10 minutes Q.26 $T_0 = 420$ K, $T_0 = 353.6$ K

EXERCISE – III

Q.1 12 gm Q.2 60° C Q.3 41.53 Watt; 26.48 ^{0}C ; 0.55^{0}C

Q.4 2×10^{-4} C Q.5 D Q.6 5.5 min

Q.7 $k = \frac{\log_e 2}{t_1}$; $T = 300 + 50 \exp.\left[-\left\{\frac{KA}{LC} + \frac{\log_e 2}{t_1}\right\}2t_1\right]$

Q.8	D	Q.9	B, D	Q.10	A	Q.11	B	Q.12	B	Q.13	D	Q.14	0.5 kg
Q.15	A	Q.16	A	Q.17	A	Q.18	(a) 595 watt/m^2, (b) $T_0 \approx 420$ K					Q.19	B
Q.20	D	Q.21	C	Q.22	$\gamma_l = 2\alpha_s$			Q.23	$\frac{K}{4e\sigma LT_S^3 + K}$			Q.24	A
Q.25	C	Q.26	A	Q.27	A	Q.28	B						

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

CAPACITANCE

CONTENTS

KEY CONCEPTS

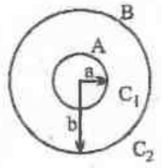
1. **CAPACITANCE OF AN ISOLATED SPHERICAL CONDUCTOR :**

   $C = 4\pi \in_0 \in_r R$ in a medium $\qquad C = 4\pi \in_0 R$ in air

   * This sphere is at infinite distance from all the conductors .
   * The capacitance $C = 4\pi \in_0 R$ exists between the surface of the sphere & earth .

2. **SPHERICAL CAPACITOR :**

   It consists of two concentric spherical shells as shown in figure. Here capacitance of region between the two shells is C_1 and that outside the shell is C_2. We have

   $$C_1 = \frac{4\pi \in_0 ab}{b-a} \qquad \text{and} \quad C_2 = 4\pi \in_0 b$$

   Depending on connection, it may have different combinations of C_1 and C_2.

3. **PARALLEL PLATE CAPACITOR :**

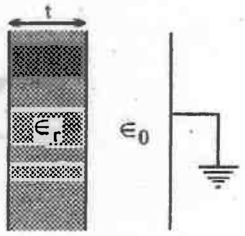
   (i) **UNIFORM DI-ELECTRIC MEDIUM :**

   If two parallel plates each of area A & separated by a distance d are charged with equal & opposite charge Q, then the system is called a parallel plate capacitor & its capacitance is given by,

   $$C = \frac{\in_0 \in_r A}{d} \text{ in a medium} \quad ; \quad C = \frac{\in_0 A}{d} \text{ with air as medium}$$

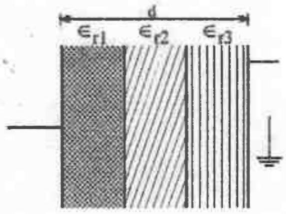
   This result is only valid when the electric field between plates of capacitor is constant.

   (ii) **MEDIUM PARTLY AIR :** $\qquad C = \dfrac{\in_0 A}{d - \left(t - \frac{t}{\in_r}\right)}$

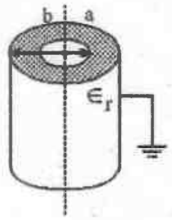
   When a di-electric slab of thickness t & relative permittivity $\in_r$ is introduced between the plates of an air capacitor, then the distance between the plates is effectively reduced by $\left(t - \frac{t}{\in_r}\right)$ irrespective of the position of the di-electric slab .

   (iii) **COMPOSITE MEDIUM :** $\qquad C = \dfrac{\in_0 A}{\frac{t_1}{\in_{r1}} + \frac{t_2}{\in_{r2}} + \frac{t_3}{\in_{r3}}}$

4. **CYLINDRICAL CAPACITOR :**

   It consist of two co-axial cylinders of radii a & b, the outer conductor is earthed . The di-electric constant of the medium filled in the space between the cylinder is $\in_r$. The capacitance per unit length is $C = \dfrac{2\pi\in_0\in_r}{\ell n\left(\frac{b}{a}\right)} \dfrac{\text{Farad}}{\text{m}}$.

5. CONCEPT OF VARIATION OF PARAMETERS:

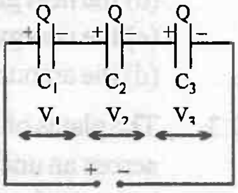
As capacitance of a parallel plate capacitor is $C = \frac{\epsilon_0 kA}{d}$, if either of k, A or d varies in the region between the plates, we choose a small dc in between the plates and for total capacitance of system.

If all dC's are in series $\frac{1}{C_T} = \int \frac{dx}{\epsilon_0 k(x) A(x)}$, If all dC's are in parallel $C_T = \int dC$

6. COMBINATION OF CAPACITORS :

(i) CAPACITORS IN SERIES :

In this arrangement all the capacitors when uncharged get the same charge Q but the potential difference across each will differ (if the capacitance are unequal).

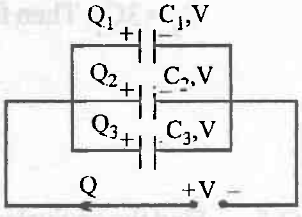


$$\frac{1}{C_{eq.}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

(ii) CAPACITORS IN PARALLEL :

When one plate of each capacitor is connected to the positive terminal of the battery & the other plate of each capacitor is connected to the negative terminals of the battery, then the capacitors are said to be in parallel connection.

The capacitors have the same potential difference, V but the charge on each one is different (if the capacitors are unequal).



$C_{eq.} = C_1 + C_2 + C_3 + ... + C_n$.

7. ENERGY STORED IN A CHARGED CAPACITOR :

Capacitance C, charge Q & potential difference V; then energy stored is

$U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$. This energy is stored in the electrostatic field set up in the di-electric medium between the conducting plates of the capacitor .

8. HEAT PRODUCED IN SWITCHING IN CAPACITIVE CIRCUIT

Due to charge flow always some amount of heat is produced when a switch is closed in a circuit which can be obtained by energy conservation as –

Heat = Work done by battery – Energy absorbed by capacitor.

9. SHARING OF CHARGES :

When two charged conductors of capacitance C_1 & C_2 at potential V_1 & V_2 respectively are connected by a conducting wire, the charge flows from higher potential conductor to lower potential conductor, until the potential of the two condensers becomes equal. The common potential (V) after sharing of charges;

$$V = \frac{\text{net charge}}{\text{net capacitance}} = \frac{q_1 + q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

charges after sharing $q_1 = C_1V$ & $q_2 = C_2V$. In this process energy is lost in the connecting wire as heat . This loss of energy is $U_{initial} - U_{real} = \frac{C_1 C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$.

10. REMEMBER :

(i) The energy of a charged conductor resides outside the conductor in its EF, where as in a condenser it is stored within the condenser in its EF.

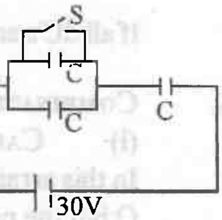
(ii) The energy of an uncharged condenser = 0 .

(iii) The capacitance of a capacitor depends only on its size & geometry & the di-electric between the conducting surface . (i.e. independent of the conductor, like, whether it is copper, silver, gold etc)

EXERCISE # I

Q.1 A solid conducting sphere of radius 10 cm is enclosed by a thin metallic shell of radius 20 cm. A charge $q = 20\mu C$ is given to the inner sphere. Find the heat generated in the process, the inner sphere is connected to the shell by a conducting wire

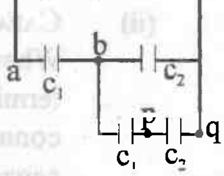
Q.2 The capacitor each having capacitance $C = 2\mu F$ are connected with a battery of emf 30 V as shown in figure. When the switch S is closed. Find
(a) the amount of charge flown through the battery
(b) the heat generated in the circuit
(c) the energy supplied by the battery
(d) the amount of charge flown through the switch S



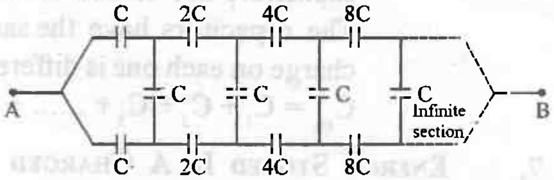
Q.3 The plates of a parallel plate capacitor are given charges +4Q and –2Q. The capacitor is then connected across an uncharged capacitor of same capacitance as first one (= C). Find the final potential difference between the plates of the first capacitor.



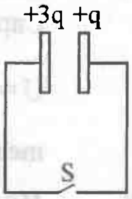
Q.4 In the given network if potential difference between p and q is 2V and $C_2 = 3C_1$. Then find the potential difference between a & b.



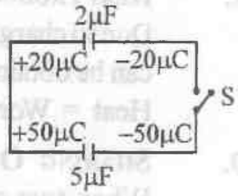
Q.5 Find the equivalent capacitance of the circuit between point A and B.



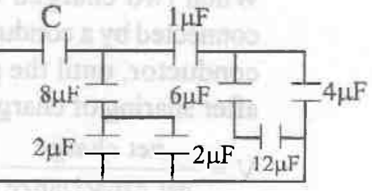
Q.6 The two identical parallel plates are given charges as shown in figure. If the plate area of either face of each plate is A and separation between plates is d, then find the amount of heat liberate after closing the switch.



Q.7 Find heat produced in the circuit shown in figure on closing the switch S.



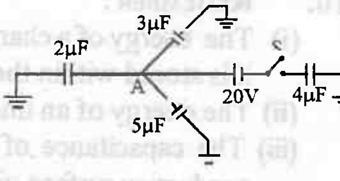
Q.8 In the following circuit, the resultant capacitance between A and B is 1 μF. Find the value of C.



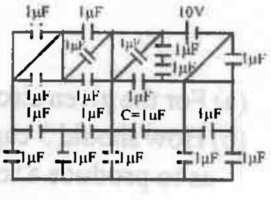
Q.9 Three capacitors of 2μF, 3μF and 5μF are independently charged with batteries of emf's 5V, 20V and 10V respectively. After disconnecting from the voltage sources. These capacitors are connected as shown in figure with their positive polarity plates are connected to A and negative polarity is earthed. Now a battery of 20V and an uncharged capacitor of 4μF capacitance are connected to the junction A as shown with a switch S. When switch is closed, find :

(a) the potential of the junction A.

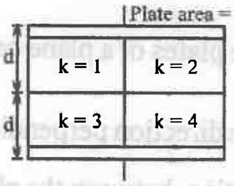
(b) final charges on all four capacitors.



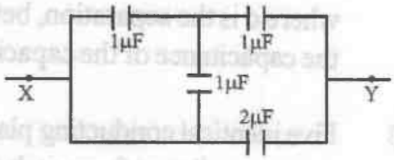
Q.10 Find the charge on the capacitor C = 1 μF in the circuit shown in the figure.



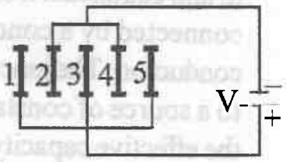
Q.11 Find the capacitance of the system shown in figure.



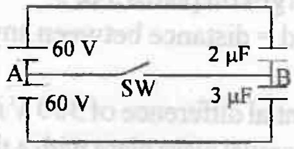
Q.12 The figure shows a circuit consisting of four capacitors. Find the effective capacitance between X and Y.



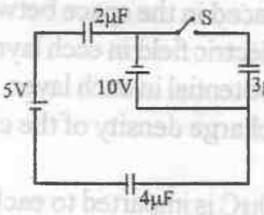
Q.13 Five identical capacitor plates, each of area A, are arranged such that adjacent plates are at a distance 'd' apart, the plates are connected to a source of emf V as shown in figure. The charge on plate 1 is_______________ and that on plate 4 is_______________.



Q.14 In the circuit shown in the figure, intially SW is open. When the switch is closed, the charge passing through the switch_______________ in the direction _______________ to _______________.



Q.15 In the circuit shown in figure, find the amount of heat generated when switch s is closed.



Q.16 Two parallel plate capacitors of capacitance C and 2C are connected in parallel then following steps are performed.
(i) A battery of voltage V is connected across points A and B.
(ii) A dielectric slab of relative permittivity k is slowly inserted in capacitor C.
(iii) Battery is disconnected.
(iv) Dielectric slab is slowly removed from capacitor.
Find the heat produced in (i) and work done by external agent in step (ii) & (iv).

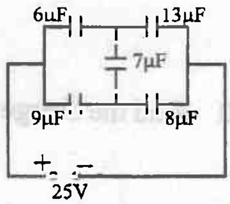
Q.17 The plates of a parallel plate capacitor are separated by a distance d = 1 cm. Two parallel sided dielectric slabs of thickness 0.7 cm and 0.3 cm fill the space between the plates. If the dielectric constants of the two slabs are 3 and 5 respectively and a potential difference of 440V is applied across the plates. Find :
(i) the electric field intensities in each of the slabs.
(ii) the ratio of electric energies stored in the first to that in the second dielectric slab.

Q.18 A 10 μF and 20 μF capacitor are connected to a 10 V cell in parallel for some time after which the capacitors are disconnected from the cell and reconnected at t = 0 with each other, in series, through wires of finite resistance. The +ve plate of the first capacitor is connected to the –ve plate of the second capacitor. Draw the graph which best describes the charge on the +ve plate of the 20 μF capacitor with increasing time.

List of recommended questions from I.E. Irodov.

3.101, 3.102, 3.103, 3.113, 3.117, 3.121, 3.122, 3.123, 3.124, 3.132, 3.133, 3.141, 3.142, 3.177, 3.184, 3.188, 3.199, 3.200, 3.201, 3.203, 3.204, 3.205

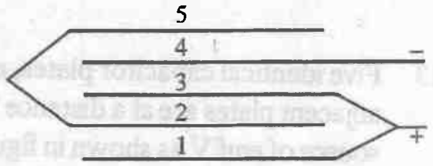
EXERCISE # II



Q.1 (a) For the given circuit. Find the potential difference across all the capacitors.
(b) How should 5 capacitors, each of capacities, 1μF be connected so as to produce a total capacitance of 3/7 μF.

Q.2 The gap between the plates of a plane capacitor is filled with an isotropic insulator whose di-electric constant varies in the direction perpendicular to the plates according to the law $K = K_1\left[1+\sin\frac{\pi}{d}X\right]$, where d is the separation, between the plates & K_1 is a constant. The area of the plates is S. Determine the capacitance of the capacitor.

Q.3 Five identical conducting plates 1, 2, 3, 4 & 5 are fixed parallel to and equdistant from each other (see figure). Plates 2 & 5 are connected by a conductor while 1 & 3 are joined by another conductor. The junction of 1 & 3 and the plate 4 are connected to a source of constant e.m.f. V_0. Find ;



(i) the effective capacity of the system between the terminals of the source.
(ii) the charges on plates 3 & 5.
Given d = distance between any 2 successive plates & A = area of either face of each plate.

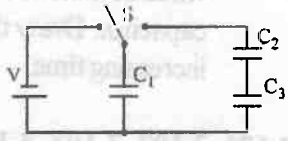
Q.4 A potential difference of 300 V is applied between the plates of a plane capacitor spaced 1 cm apart. A plane parallel glass plate with a thickness of 0.5 cm and a plane parallel paraffin plate with a thickness of 0.5 cm are placed in the space between the capacitor plates find :
(i) Intensity of electric field in each layer.
(ii) The drop of potential in each layer.
(iii) The surface charge density of the charge on capacitor the plates. Given that : $k_{glass} = 6$, $k_{paraffin} = 2$

Q.5 A charge 200μC is imparted to each of the two identical parallel plate capacitors connected in parallel. At t = 0, the plates of both the capacitors are 0.1m apart. The plates of first capacitor move towards each other with relative velocity 0.001m/s and plates of second capacitor move apart with the same velocity. Find the current in the circuit at the moment.

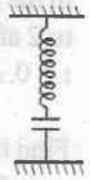
Q.6 A parallel plate capacitor has plates with area A & separation d. A battery charges the plates to a potential difference of V_0. The battery is then disconnected & a di-electric slab of constant K & thickness d is introduced. Calculate the positive work done by the system (capacitor + slab) on the man who introduces the slab.

Q.7 A capacitor of capacitance C_0 is charged to a potential V_0 and then isolated. A small capacitor C is then charged from C_0, discharged & charged again, the process being repeated n times. The potential of the large capacitor has now fallen to V. Find the capacitance of the small capacitor. If V_0 = 100 volt, V=35volt, find the value of n for C_0 = 0.2 μF & C = 0.01075 μF. Is it possible to remove charge on C_0 this way?

Q.8 When the switch S in the figure is thrown to the left, the plates of capacitors C_1 acquire a potential difference V. Initially the capacitors C_2C_3 are uncharged. Thw switch is now thrown to the right. What are the final charges q_1, q_2 & q_3 on the corresponding capacitors.



Q.9 A parallel plate capacitor with air as a dielectric is arranged horizontally. The lower plate is fixed and the other connected with a vertical spring. The area of each plate is A. In the steady position, the distance between the plates is d_0. When the capacitor is connected with an electric source with the voltage V, a new equilibrium appears, with the distance between the plates as d_1. Mass of the upper plates is m.



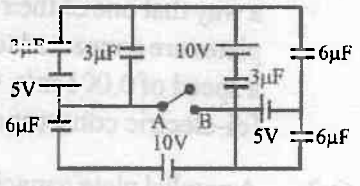
(i) Find the spring constant K.
(ii) What is the maximum voltage for a given K in which an equilibrium is possible ?
(iii) What is the angular frequency of the oscillating system around the equilibrium value d_1. (take amplitude of oscillation $<< d_1$)

Q.10 An insolated conductor initially free from charge is charged by repeated contacts with a plate which after each contact has a charge Q due to some mechanism. If q is the charge on the conductor after the first operation, prove that the maximum charge which can be given to the conductor in this way is $\frac{Qq}{Q-q}$.

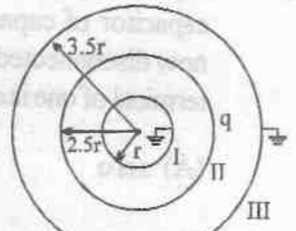
Q.11 A parallel plate capacitor is filled by a di-electric whose relative permittivity varies with the applied voltage according to the law = αV, where $\alpha = 1$ per volt. The same (but containing no di-electric) capacitor charged to a voltage V = 156 volt is connected in parallel to the first "non-linear" uncharged capacitor. Determine the final voltage V_f across the capacitors.

Q.12 A capacitor consists of two air spaced concentric cylinders. The outer of radius b is fixed, and the inner is of radius a. If breakdown of air occurs at field strengths greater than E_b, show that the inner cylinder should have
(i) radius a = b/e if the potential of the inner cylinder is to be maximum
(ii) radius a = $b/\sqrt{e}$ if the energy per unit length of the system is to be maximum.

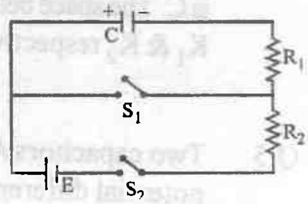
Q.13 Find the charge flown through the switch from A to B when it is closed.



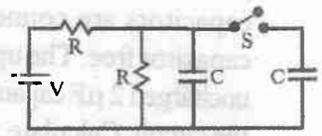
Q.14 Figure shows three concentric conducting spherical shells with inner and outer shells earthed and the middle shell is given a charge q. Find the electrostatic energy of the system stored in the region I and II.



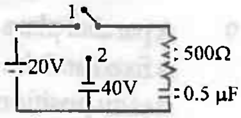
Q.15 The capacitors shown in figure has been charged to a potential difference of V volts, so that it carries a charge CV with both the switches S_1 and S_2 remaining open. Switch S_1 is closed at t=0. At t=R_1C switch S_1 is opened and S_2 is closed. Find the charge on the capacitor at t=$2R_1C + R_2C$.



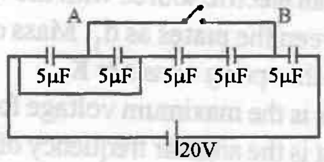
Q.16 In the figure shown initially switch is open for a long time. Now the switch is closed at t = 0. Find the charge on the rightmost capacitor as a function of time given that it was intially unchanged.



Q.17 In the given circuit, the switch is closed in the position 1 at t = 0 and then moved to 2 after 250 μs. Derive an expression for current as a function of time for t > 0. Also plot the variation of current with time.

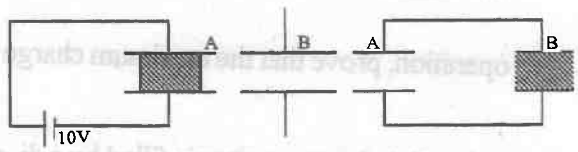


Q.18 Find the charge which flows from point A to B, when switch is closed.



EXERCISE # III

Q.1 Two parallel plate capacitors A & B have the same separation $d = 8.85 \times 10^{-4}$ m between the plates. The plate areas of A & B are 0.04 m^2 & 0.02 m^2 respectively. A slab of di-electric constant (relative permittivity) K=9 has dimensions such that it can exactly fill the space between the plates of capacitor B.



(i) the di-electric slab is placed inside A as shown in the figure (i) A is then charged to a potential difference of 110 volt. Calculate the capacitance of A and the energy stored in it.

(ii) the battery is disconnected & then the di-electric slab is removed from A. Find the work done by the external agency in removing the slab from A.

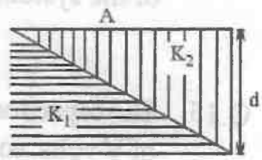
(iii) the same di-electric slab is now placed inside B, filling it completely. The two capacitors A & B are then connected as shown in figure (iii). Calculate the energy stored in the system. [JEE '93, 7]

Q.2 Two square metallic plates of 1 m side are kept 0.01 m apart, like a parallel plate capacitor, in air in such a way that one of their edges is perpendicular, to an oil surface in a tank filled with an insulating oil. The plates are connected to a battery of e.m.f. 500 volt. The plates are then lowered vertically into the oil at a speed of 0.001 m/s. Calculate the current drawn from the battery during the process. [di-electric constant of oil = 11, $\epsilon_0 = 8.85 \times 10^{-12}$ $C^2/N^2 m^2$] [JEE '94, 6]

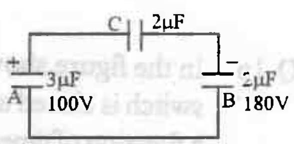
Q.3 A parallel plate capacitor C is connected to a battery & is charged to a potential difference V. Another capacitor of capacitance 2C is similarly charged to a potential difference 2V volt. The charging battery is now disconnected & the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of other. The final energy of the configuration is :

(A) zero (B) $\frac{3}{2}$ CV^2 (C) $\frac{25}{6}$ CV^2 (D) $\frac{9}{2}$ CV^2 [JEE '95, 1]

Q.4 The capacitance of a parallel plate capacitor with plate area 'A' & separation d is C. The space between the plates is filled with two wedges of di-electric constant K_1 & K_2 respectively. Find the capacitance of the resulting capacitor. [JEE '96, 2]



Q.5 Two capacitors A and B with capacities 3 μF and 2 μF are charged to a potential difference of 100 V and 180 V respectively. The plates of the capacitors are connected as shown in figure with one wire from each capacitor free. The upper plate of a is positive and that of B is negative. an uncharged 2 μF capacitor C with lead wires falls on the free ends to complete the circuit. Calculate :

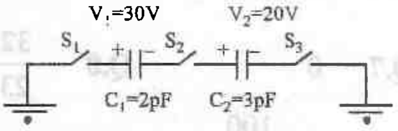


(i) the final charges on the three capacitors

(ii) The amount of electrostatic energy stored in the system before and after the completion of the circuit. [JEE '97 (cancelled)]

Q.6 An electron enters the region between the plates of a parallel plate capacitor at a point equidistant from either plate. The capacitor plates are 2×10^{-2} m apart & 10^{-1} m long. A potential difference of 300 volt is kept across the plates. Assuming that the initial velocity of the electron is parallel to the capacitor plates, calculate the largest value of the velocity of the electron so that they do not fly out of the capacitor at the other end. [JEE '97, 5]

Q.7 For the circuit shown, which of the following statements is true ?



(A) with S_1 closed, $V_1 = 15$ V, $V_2 = 20$ V
(B) with S_3 closed, $V_1 = V_2 = 25$ V
(C) with S_1 & S_2 closed, $V_1 = V_2 = 0$
(D) with S_1 & S_2 closed, $V_1 = 30$ V, $V_2 = 20$ V [JEE '99, 2]

Q.8 Calculate the capacitance of a parallel plate condenser, with plate area A and distance between plates d, when filled with a medium whose permittivity varies as ;

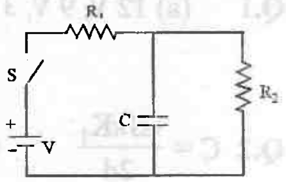
$$\in(x) = \in_0 + \beta x \qquad 0 < x < \frac{d}{2}$$

$$\in(x) = \in_0 + \beta\,(d - x) \qquad \frac{d}{2} < x < d.$$ [REE 2000, 6]

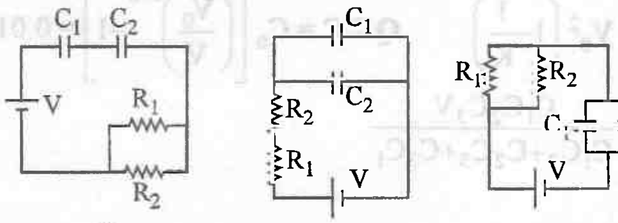
Q.9 Two identical capacitors, have the same capacitance C. One of them is charged to potential V_1 and the other to V_2. The negative ends of the capacitors are connected together. When the positive ends are also connected, the decrease in energy of the combined system is [JEE 2002 (Scr), 3]

(A) $\frac{1}{4}C(V_1^2 - V_2^2)$ (B) $\frac{1}{4}C(V_1^2 + V_2^2)$ (C) $\frac{1}{4}C(V_1 - V_2)^2$ (D) $\frac{1}{4}C(V_1 + V_2)^2$

Q.10 In the given circuit, the switch S is closed at time t = 0. The charge Q on the capacitor at any instant t is given by $Q(t) = Q_0(1 - e^{-\alpha t})$. Find the value of Q_0 and α in terms of given parameters shown in the circuit. [JEE 2005]



Q.11 Given : $R_1 = 1\Omega$, $R_2 = 2\Omega$, $C_1 = 2\mu F$, $C_2 = 4\mu F$
The time constants (in μS) for the circuits I, II, III are respectively



(I) (II) (III)

(A) 18, 8/9, 4 (B) 18, 4, 8/9
(C) 4, 8/9, 18 (D) 8/9, 18, 4 [JEE 2006]

ANSWER KEY

EXERCISE # I

Q.1 9J **Q.2** (a) 20 μC, (b) 0.3 mJ, (c) 0.6 mJ. (d) 60 μC

Q.3 3Q/2C **Q.4** 30 V **Q.5** C **Q.6** $\frac{1}{2}\frac{q^2 d}{\epsilon_0 A}$

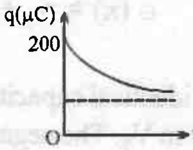
Q.7 0 **Q.8** $\frac{32}{23}$ μF

Q.9 (a) $\frac{100}{7}$ volts; (b) 28.56 μC, 42.84 μC, 71.4 μC, 22.88 μC **Q.10** 10 μC

Q.11 $\frac{25}{24}\frac{\varepsilon_0 A}{d}$ **Q.12** $\frac{8}{3}$μF **Q.13** $\frac{A\epsilon_0 V}{d}, \frac{2A\epsilon_0 V}{d}$ **Q.14** 60 μc , A to B

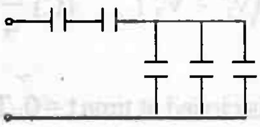
Q.15 150 μJ **Q.16** (i) $\frac{3}{2}CV^2$; (ii) $-\frac{1}{2}CV^2(K-1)$; $\frac{1}{6}(K+2)(K-1)CV^2$;

Q.17 (i) 5×10^4 V/m , 3×10^4 V/m; (ii) 35/9 **Q.18**



EXERCISE # II

Q.1 (a) 12 V, 9 V, 3 V, 13 V, 16 V , (b)



Q.2 $C = \frac{\in S\pi K_1}{2d}$ **Q.3** (i) $\frac{5}{3}\left(\frac{\epsilon_0 A}{d}\right)$; (ii) $Q_3 = \frac{4}{3}\left(\frac{\epsilon_0 AV}{d}\right)$, $Q_5 = \frac{2}{3}\left(\frac{\epsilon_0 AV}{d}\right)$

Q.4 (i) 1.5×10^4 V/m, 4.5×10^4 V/m, (ii) 75 V, 225 V, (iii) 8×10^{-7} C/m^2

Q.5 2μA **Q.6** $W = \frac{1}{2}C_0 V_0^2\left(1 - \frac{1}{K}\right)$ **Q.7** $C = C_0\left[\left(\frac{V_0}{V}\right)^{1/n} - 1\right] = 0.01078$ μF, n = 20

Q.8 $q_1 = \frac{C_1^2 V(C_2+C_3)}{C_1C_2+C_2C_3+C_1C_3}$ $q_2 = q_3 \frac{C_1C_2C_3V}{C_1C_2+C_2C_3+C_3C_1}$

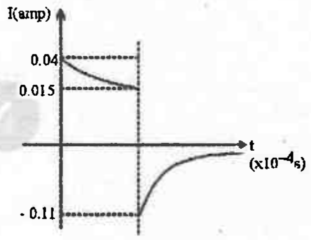
Q.9 $\frac{\varepsilon_0 AV^2}{2d_1^2(d_0-d_1)}, \sqrt{\frac{K}{A\varepsilon_0}}\left(\frac{2}{3}d_0\right)^{3/2}, \left[\frac{Kd_1^3 - \epsilon_0 AV^2}{md_1^3}\right]^{1/2}$ **Q.11** 12 volt **Q.13** 69 mC

Q.14 $U_I = \frac{3kq_1^2}{10r}$ *where* $q_1 = -\frac{4q}{25}$; $U_{II} = 2K(q+q_1)^2/35r$ **Q.15** $q = CE\left(1 - \frac{1}{e}\right) + \frac{CV}{e^2}$

Q.16 $q = \frac{CV}{2}\left(1 - \frac{1}{2}e^{-t/RC}\right)$

Q.17 For $t < 250\ \mu s$, $I = 0.04\ e^{-4000\,t}$ amp ;

For $t > 250\ \mu s$, $I = -\ 0.11e^{-4000(t-250)\times10^{-6}}$ amp,



Q.18 $-\dfrac{400}{7}\ \mu C$

EXERCISE # III

Q.1 (i) 0.2×10^{-8} F, 1.2×10^{-5} J ; (ii) 4.84×10^{-5} J ; (iii) 1.1×10^{-5} J

Q.2 4.425×10^{-9} Ampere **Q.3** B **Q.4** $\dfrac{CK_1K_2}{(K_2-K_1)}\ \ln\dfrac{K_2}{K_1}$

Q.5 $Q_A = 90\ \mu C$, $Q_B = 150\ \mu C$, $Q_C = 210\ \mu C$, $U_i = 47.4$ mJ, $U_f = 18$ mJ

Q.6 $\dfrac{\sqrt{4.8}}{2\sqrt{9.1}} \times 10^{6}$ m/s **Q.7** D **Q.8** $\dfrac{\beta A}{2}\Big/\ell n\left(\dfrac{2\epsilon_0 + \beta d}{2\epsilon_0}\right)$

Q.9 C **Q.10** $Q_0 = \dfrac{CVR_2}{R_1 + R_2}$ and $a = \dfrac{R_1 + R_2}{CR_1R_2}$ **Q.11** D

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

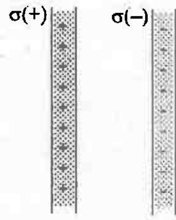
CAPACITANCE

QUESTION FOR SHORT ANSWER

Q.1 The electric strength of air is about 30, 000 V/cm. By this we mean that when the electric field intensity exceeds this value, a spark will jump through the air. We say that "electric breakdown" has occurred. Using this value, estimate the potential difference between two objects where a spark jumps. A typical situation might be the spark that jumps between your body and a metal door handle after you have walked on a deep carpet or slid across a plastic car seat in very dry weather.

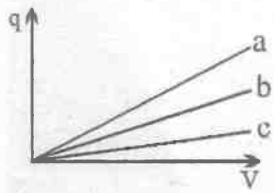
Q.2 If you grasp the two wires leading from the two plates of a charged capacitor, you may feel a shock. The effect is much greater for a 2–μF capacitor than for a 0.02μF capacitor, even though both are are charged to the same potential difference. Why?

Q.3 Three infinite nonconducting sheets, with uniform surface charge densities σ, 2σ and 3σ are arranged to be parallel like the two sheets in Fig. What is their order, from left to right, if the electric field $\vec{E}$ produced by the arrangement has magnitude $E = 0$ in one region and $E = 2\sigma/\varepsilon_0$ in another region?



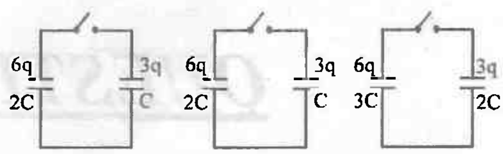
Q.4 As shown in the figure plots of charge versus potential difference for three parallel plate capacitors, which have the plate areas and separations given in the table. Which of the plots goes with which of the capacitors?

Capacitor	Area	Separation
1	A	d
2	2A	d
3	A	2d

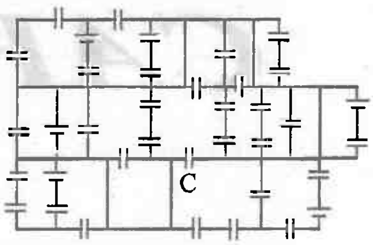


Q.5 Initially, a single capacitance C_1 is wired to a battery. Then capacitance C_2 is added in parallel. Are (a) the potential difference across C_1 and (b) the charge q_1 on C_1 now more than, less than, or the same as previously? (c) Is the equivalent capacitance C_{12} of C_1 and C_2 more than, less than, or equal to C_1? (d) Is the total charge stored on C_1 and C_2 together more than, less than, or equal to the charge stored previously on C_1?

Q.6 As shown in the figure three circuits, each consisting of a switch and two capacitors, initially charged as indicated. After the switches have been closed, in which circuit (if any) will the charge on the left–hand capacitor (a) increase, (b) decrease and (c) remain the same?



Q.7 Cap-monster maze. In the Figure all the capacitors have a capacitance of 6.0 μF, and all the batteries have an emf of 10V. What is the charge on capacitor C? (If you can find the proper loop through this maze, you can answer the question with a few seconds of mental calculation.)



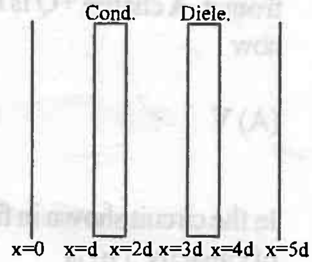
Q.8 An oil filled capacitor has been designed to have a capacitance C and to operate safely at or below a certain maximum potential difference V_m without arcing over. However, the designer did not do a good job and the capacitor occasionally arcs over. What can be done to redesign the capacitor, keeping C and V_m unchanged and using the same dielectric?

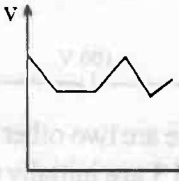
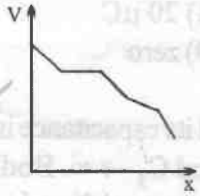
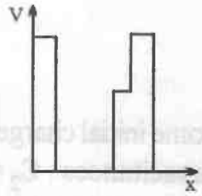
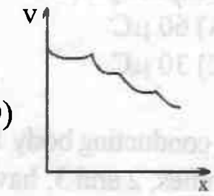
Q.9 One of the plates of a capacitor connected to battery is earthed. Will the potential diffrence between the plates change if the earthing wire is removed?

ONLY ONE OPTION IS CORRECT.

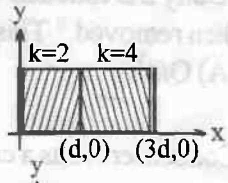
Take approx. 2 minutes for answering each question.

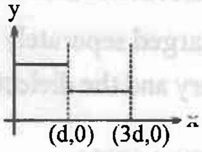
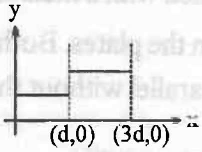
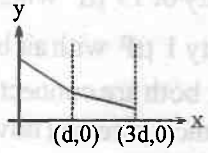
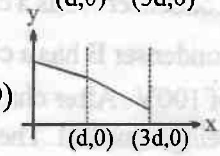
Q.1 The distance between plates of a parallel plate capacitor is 5d. Let the positively charged plate is at x=0 and negatively charged plate is at x=5d. Two slabs one of conductor and other of a dielectric of equal thickness d are inserted between the plates as shown in figure. Potential versus distance graph will look like :



(A) 
(B) 
(C) 
(D) 

Q.2 A parallel plate capacitor has two layers of dielectric as shown in figure. This capacitor is connected across a battery. The graph which shows the variation of electric field (E) and distance (x) from left plate.

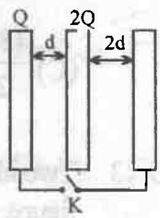


(A) 
(B) 
(C) 
(D) 

Q.3 The distance between the plates of a charged parallel plate capacitor is 5 cm and electric field inside the plates is 200 Vcm^{-1}. An uncharged metal bar of width 2 cm is fully immersed into the capacitor. The length of the metal bar is same as that of plate of capacitor. The voltage across capacitor after the immersion of the bar is

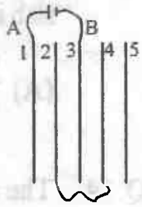
(A) zero (B) 400 V (C) 600 V (D) 100 V

Q.4 Three large plates are arranged as shown. How much charge will flow through the key k if it is closed?



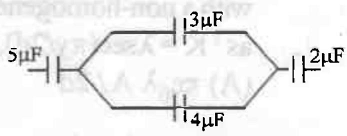
(A) $\frac{5Q}{6}$ (B) $\frac{4Q}{3}$ (C) $\frac{3Q}{2}$ (D) none

Q.5 Five conducting parallel plates having area A and separation between them d, are placed as shown in the figure. Plate number 2 and 4 are connected wire and between point A and B, a cell of emf E is connected. The charge flown through the cell is



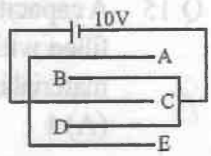
(A) $\frac{3}{4}\frac{\varepsilon_0 AE}{d}$ (B) $\frac{2}{3}\frac{\varepsilon_0 AE}{d}$ (C) $\frac{4\varepsilon_0 AE}{d}$ (D) $\frac{\varepsilon_0 AE}{2d}$

Q.6 If charge on left plane of the 5μF capacitor in the circuit segment shown in the figure is –20μC, the charge on the right plate of 3μF capacitor is



(A) +8.57 μC (B) –8.57 μC (C) +11.42 μC (D) –11.42 μC

Q.7 Five identical capacitor plates are arranged such that they make capacitors each of 2 μF. The plates are connected to a source of emf 10 V. The charge on plate C is

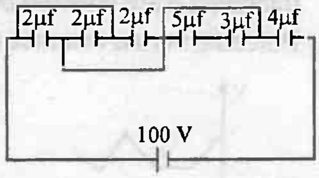


(A) + 20 μC (B) + 40 μC (C) + 60 μC (D) + 80 μC

Q.8 A capacitor of capacitance C is charged to a potential difference V from a cell and then disconnected from it. A charge +Q is now given to its positive plate. The potential difference across the capacitor is now

(A) V (B) $V+\frac{Q}{C}$ (C) $V+\frac{Q}{2C}$ (D) $V-\frac{Q}{C}$, if $V < CV$

Q.9 In the circuit shown in figure charge stored in the capacitor of capacity 5 μf is

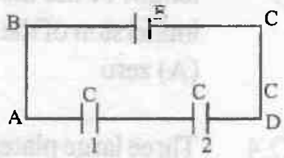


(A) 60 μC (B) 20 μC
(C) 30 μC (D) zero

Q.10 A conducting body 1 has some initial charge Q, and its capacitance is C. There are two other conducting bodies, 2 and 3, having capacitances : $C_2 = 2C$ and $C_3 \to \infty$. Bodies 2 and 3 are initially uncharged. "Body 2 is touched with body 1. Then, body 2 is removed from body 1 and touched with body 3, and then removed." This process is repeated N times. Then, the charge on body 1 at the end must be
(A) $Q/3^N$ (B) $Q/3^{N-1}$ (C) Q/N^3 (D) None

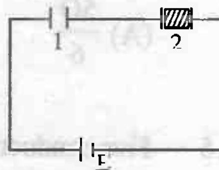
Q.11 Condenser A has a capacity of 15 μF when it is filled with a medium of dielectric constant 15. Another condenser B has a capacity 1 μF with air between the plates. Both are charged separately by a battery of 100V. After charging, both are connected in parallel without the battery and the dielectric material being removed. The common potential now is
(A) 400V (B) 800V (C) 1200V (D) 1600V

Q.12 In the adjoining figure, capacitor (1) and (2) have a capacitance 'C' each. When the dielectric of dielectric consatnt K is inserted between the plates of one of the capacitor, the total charge flowing through battery is



(A) $\frac{KCE}{K+1}$ from B to C (B) $\frac{KCE}{K+1}$ from C to B
(C) $\frac{(K-1)CE}{2(K+1)}$ from B to C (D) $\frac{(K-1)CE}{2(K+1)}$ from C to B

Q.13 Two identical capacitors 1 and 2 are connected in series to a battery as shown in figure. Capacitor 2 contains a dielectric slab of dielectric constant k as shown. Q_1 and Q_2 are the charges stored in the capacitors. Now the dielectric slab is removed and the corresponding charges are Q'_1 and Q'_2. Then



(A) $\frac{Q'_1}{Q_1}=\frac{k+1}{k}$ (B) $\frac{Q'_2}{Q_2}=\frac{k+1}{2}$ (C) $\frac{Q'_2}{Q_2}=\frac{k+1}{2k}$ (D) $\frac{Q'_1}{Q_1}=\frac{k}{2}$

Q.14 The area of the plates of a parallel plate capacitor is A and the gap between them is d. The gap is filled with a non-homogeneous dielectric whose dielectric constant varies with the distance 'y' from one plate as : $K = \lambda\sec(\pi y/2d)$, where λ is a dimensionless constant. The capacitance of this capacitor is
(A) $\pi\varepsilon_0\lambda A/2d$ (B) $\pi\varepsilon_0\lambda A/d$ (C) $2\pi\varepsilon_0\lambda A/d$ (D) none

Q.15 A capacitor stores 60μC charge when connected across a battery. When the gap between the plates is filled with a dielectric , a charge of 120μC flows through the battery. The dielectric constant of the material inserted is :
(A) 1 (B) 2 (C) 3 (D) none

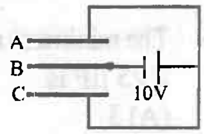
Q.16 In the **above question**, if the initial capacitance of the capacitor was 2μF, the amount of heat produced when the dielectric is inserted.

(A) 3600μJ (B) 2700μJ (C) 1800μJ (D) none

Q.17 A capacitor of capacitance C is initially charged to a potential difference of V volt. Now it is connected to a battery of 2V with opposite polarity. The ratio of heat generated to the final energy stored in the capacitor will be

(A) 1.75 (B) 2.25 (C) 2.5 (D) 1/2

Q.18 Three plates A, B and C each of area 0.1 m² are separated by 0.885 mm from each other as shown in the figure. A 10 V battery is used to charge the system. The energy stored in the system is



(A) 1 μJ (B) 10^{-1} μJ (C) 10^{-2} μJ (D) 10^{-3} μJ

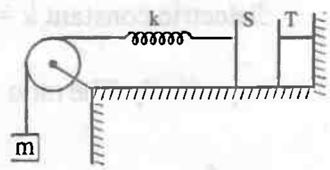
Q.19 A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance 2C is similarly charged to a potential difference 2V. The charging battery is now disconnected and the capacitors are connect in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is

(A) zero (B) $\frac{3}{2}CV^2$ (C) $\frac{25}{6}CV^2$ (D) $\frac{9}{2}CV^2$

Q.20 A 2 μF capacitor is charged to a potential = 10V. Another 4 μF capacitor is charged to a potential = 20V. The two capacitors are then connected in a single loop, with the positive plate of one connected with negative plate of the other. What heat is evolved in the circuit?

(A) 300 μJ (B) 600 μJ (C) 900 μJ (D) 450 μJ

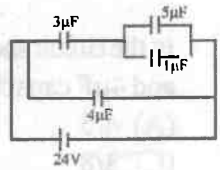
Q.21 The plates S and T of an uncharged parallel plate capacitor are connected across a battery. The battery is then disconnected and the charged plates are now connected in a system as shown in the figure. The system shown is in equilibrium. All the strings are insulating and massless. The magnitude of charge on one of the capacitor plates is: [Area of plates = A]



(A) $\sqrt{2mgA\epsilon_0}$ (B) $\sqrt{\frac{4mgA\epsilon_0}{k}}$

(C) $\sqrt{mgA\epsilon_0}$ (D) $\sqrt{\frac{2mgA\epsilon_0}{k}}$

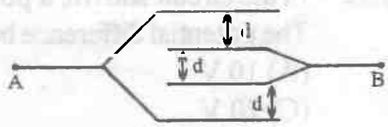
Q.22 In the circuit shown, the energy stored in 1μF capacitor is



(A) 40 μJ (B) 64 μJ

(C) 32 μJ (D) none

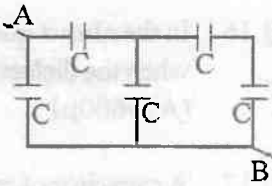
Q.23 Four metallic plates arearranged as shown in the figure. If the distance between each plate then capacitance of the given system between points A and B is (Given d << A)



(A) $\frac{\varepsilon_0 A}{d}$ (B) $\frac{2\varepsilon_0 A}{d}$

(C) $\frac{3\varepsilon_0 A}{d}$ (D) $\frac{4\varepsilon_0 A}{d}$

Q.24 What is the equivalent capacitance of the system of capacitors between A & B



(A) $\frac{7}{6}$C (B) 1.6 C (C) C (D) None

Q.25 From a supply of identical capacitors rated 8 μF, 250 V, the minimum number of capacitors required to form a composite 16 μF, 1000 V is :
(A) 2 (B) 4 (C) 16 (D) 32

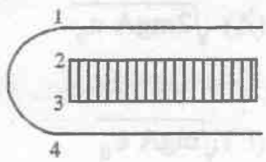
Q.26 The minimum number of capacitors each of 3 μF required to make a circuit with an equivalent capacitance 2.25 μF is
(A) 3 (B) 4 (C) 5 (D) 6

Q.27 The capacitance (C) for an isolated conducting sphere of radius (a) is given by $4\pi\varepsilon_0 a$. If the sphere is enclosed with an earthed concentric sphere. The ratio of the radii of the spheres being $\frac{n}{(n-1)}$ then the capacitance of such a sphere will be increased by a factor
(A) n (B) $\frac{n}{(n-1)}$ (C) $\frac{(n-1)}{n}$ (D) a . n

Q.28 Two capacitor having capacitances 8 μF and 16 μF have breaking voltages 20 V and 80 V. They are combined in series. The maximum charge they can store individually in the combination is
(A) 160 μC (B) 200 μC (C) 1280 μC (D) none of these

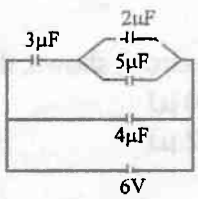
Q.29 A capacitor of capacitance 1 μF withstands the maximum voltage 6 kV while a capacitor of 2 μF withstands the maximum voltage 4 kV. What maximum voltage will the system of these two capacitor withstands if they are connected in series?
(A) 10 kV (B) 12 kV (C) 8 kV (D) 9 kV

Q.30 Four identical plates 1, 2, 3 and 4 are placed parallel to each other at equal distance as shown in the figure. Plates 1 and 4 are joined together and the space between 2 and 3 is filled with a dielectric of dielectric constant k = 2. The capacitance of the system between 1 and 3 & 2 and 4 are C_1 and C_2 respectively. The ratio $\frac{C_1}{C_2}$ is :



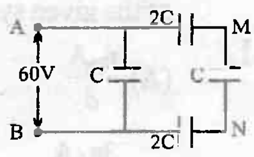
(A) $\frac{5}{3}$ (B) 1 (C) $\frac{3}{5}$ (D) $\frac{5}{7}$

Q.31 In the circuit shown in figure, the ratio of charges on 5μF and 4μF capacitor is :



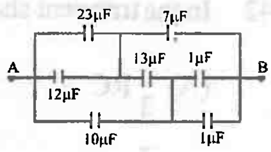
(A) 4/5 (B) 3/5
(C) 3/8 (D) 1/2

Q.32 In the circuit shown, a potential difference of 60V is applied across AB. The potential difference between the point M and N is



(A) 10 V (B) 15 V
(C) 20 V (D) 30 V

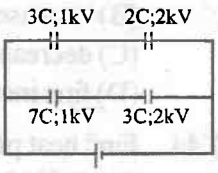
Q.33 Find the equivalent capacitance across A& B



(A) $\frac{28}{3}$ μf (B) $\frac{15}{2}$ μF
(C) 15 μF (D) none

Q.34 A capacitor of capacitance 1 μF with stands the maximum voltages 6 KV while a capacitor of capacitance 2.0 μF with stands the maximum voltage = 4KV. if the two capacitors are connected in series, then the two capacitors combined can take up a maximum voltage of
(A) 2.4 KV (B) 5 KV (C) 9 KV (D) 10 KV

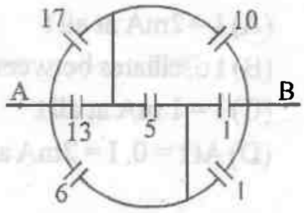
Q.35 The diagram shows four capacitors with capacitances and break down voltages as mentioned. What should be the maximum value of the external emf source such that no capacitor breaks down?[Hint: First of all find out the break down voltages of each branch. After that compare them.]



(A) 2.5 kV (B) 10 / 3kV (C) 3 kV (D) 1 kV

Q.36 Three capacitors 2 μF, 3 μF and 5 μF can withstand voltages to 3V, 2V and 1V respectively. Their series combination can withstand a maximum voltage equal to
(A) 5 Volts (B) (31/6) Volts (C) (26/5) Volts (D) None

Q.37 Find equivalent capacitance across AB (all capacitances in μF)

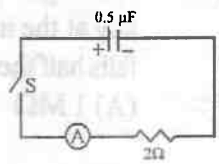


(A) $\frac{20}{3}$ μF (B) 9μF
(C) 48 μF (D) None

Q.38 Three long concentric conducting cylindrical shells have radii R, 2R and $2\sqrt{2}$ R. Inner and outer shells are connected to each other. The capacitance across middle and inner shells per unit length is:

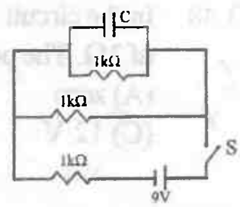
(A) $\frac{\frac{1}{3}\epsilon_0}{ln\,2}$ (B) $\frac{6\pi\epsilon_0}{ln\,2}$ (C) $\frac{\pi\epsilon_0}{2ln\,2}$ (D) None

Q.39 A charged capacitor is allowed to discharge through a resistance 2Ω by closing the switch S at the instant t = 0. At time t = $ln\,2$ μs, the reading of the ammeter falls half of its initial value. The resistance of the ammeter equal to



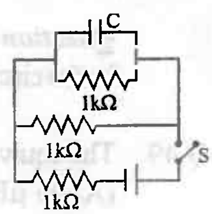
(A) 0 (B) 2Ω
(C) ∞ (D) 2MΩ

Q.40 A capacitor C = 100 μF is connected to three resistor each of resistance 1 kΩ and a battery of emf 9V. The switch S has been closed for long time so as to charge the capacitor. When switch S is opened, the capacitor discharges with time constant



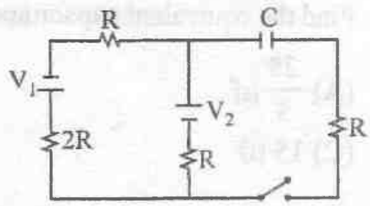
(A) 33 ms (B) 5 ms
(C) 3.3 ms (D) 50 ms

Q.41 A capacitor C = 100 μF is connected to three resistors each of resistance 1 kW and a battery of emf 9V. The switch S has been closed for long time so as to charge the capacitor. When switch S is opened, the capacitor discharges with time constant.



(A) 33 ms (B) 5 ms (C) 3.3 ms (D) 50 ms

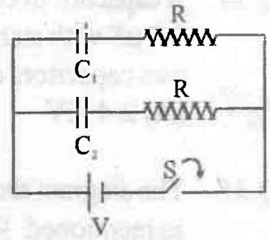
Q.42 In the transient shown the time constant of the circuit is :



(A) $\frac{5}{3}$RC (B) $\frac{5}{2}$RC

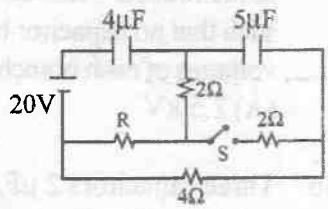
(C) $\frac{7}{4}$RC (D) $\frac{7}{3}$RC

Q.43 In the circuit shown in figure $C_1=2C_2$. Switch S is closed at time t=0. Let i_1 and i_2 be the currents flowing through C_1 and C_2 at any time t, then the ratio i_1/i_2



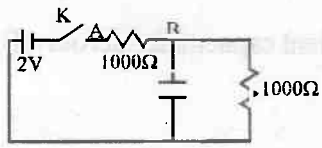
(A) is constant
(B) increases with increase in time t
(C) decreases with increase in time t
(D) first increases then decreases

Q.44 Find heat produced in the capacitors on closing the switch S



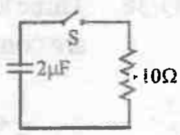
(A) 0.0002 J (B) 0.0005 J
(C) 0.00075 (D) zero

Q.45 In the circuit shown, when the key k is pressed at time t = 0, which of the following statements about current I in the resistor AB is true



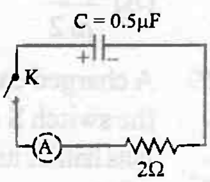
(A) I = 2mA at all t
(B) I oscillates between 1 mA and 2mA
(C) I = 1 mA at all t
(D) At t = 0, I = 2mA and with time it goes to 1 mA

Q.46 In the R–C circuit shown in the figure the total energy of 3.6×10^{-3} J is dissipated in the 10 Ω resistor when the switch S is closed. The initial charge on the capacitor is



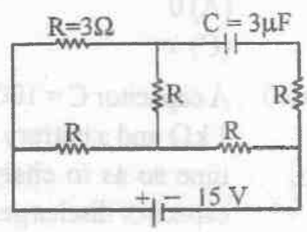
(A) 60 μC (B) 120 μC (C) $60\sqrt{2}$ μC (D) $\frac{60}{\sqrt{2}}$ μC

Q.47 A charged capacitor is allowed to discharge through a resistor by closing the key at the instant t = 0. At the instant t = (ln 4) μs, the reading of the ammeter falls half the initial value. The resistance of the ammeter is equal to



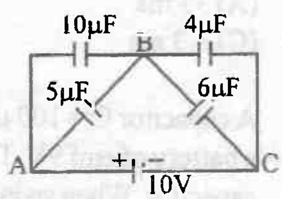
(A) 1 MΩ (B) 1Ω (C) 2Ω (D) 2MΩ

Q.48 In the circuit shown, the cell is ideal, with emf = 15 V. Each resistance is of 3Ω. The potential difference across the capacitor is



(A) zero (B) 9 V
(C) 12 V (D) 15 V

Question No. 49 to 52 (4 questions)
In the circuit shown in figure, four capacitors are connected to a battery.



Q.49 The equivalent capacitance of the circuit is
(A) 25 μF (B) 6 μF (C) 8.4 μF (D) none

Q.50 The charge on the 5 μF capacitor is
(A) 60 μC (B) 24 μC (C) 12 μC (D) 20 μC

Q.51 The potential difference across the 6 μF capacitor is
(A) 6V (B) 4V (C) 5V (D) none

Q.52 The maximum energy is stored in the capacitor of
(A) 10 μF (B) 6 μF (C) 5 μF (D) 4 μF

Q.53 A parallel plate capacitor has an electric field of 10^5V/m between the plates. If the charge on the capacitor plate is 1μC, then the force on each capacitor plate is
(A) 0.1Nt (B) 0.05Nt (C) 0.02Nt (D) 0.01Nt

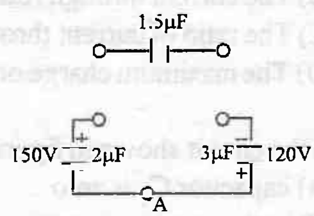
Q.54 A capacitor is connected to a battery. The force of attraction between the plates when the separation between them is halved
(A) remains the same
(B) becomes eight times
(C) becomes four times
(D) becomes two times

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

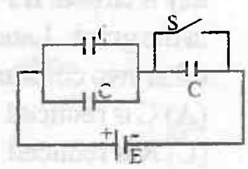
Take approx. 3 minutes for answering each question.

Q.1 A parallel plate capacitor A is filled with a dielectric whose dielectric constant varies with applied voltage as K = V. An identical capacitor B of capacitance C_0 with air as dielectric is connected to voltage source V_0 = 30V and then connected to the first capacitor after disconnecting the voltage source. The charge and voltage on capacitor.
(A) A are $25C_0$ and 25V
(B) A are $25C_0$ and 5 V
(C) B are $5c_0$ and 5V
(D) B are $5C_0$ and 25 V

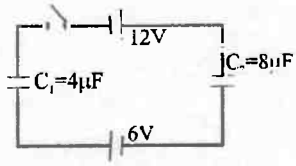
Q.2 Two capacitors of 2 μF and 3 μF are charged to 150 volt and 120 volt respectively. The plates of capacitor are connected as shown in the figure. A discharged capacitor of capacity 1.5 μF falls to the free ends of the wire. Then
(A) charge on the 1.5 μF capacitors is 180 μC
(B) charge on the 2μF capacitor is 120 μC
(C) charge flows through A from right to left.
(D) charge flows through A from left to right.



Q.3 In the circuit shown, each capacitor has a capacitance C. The emf of the cell is E. If the switch S is closed
(A) positive charge will flow out of the positive terminal of the cell
(B) positive charge will enter the positive terminal of the cell
(C) the amount of charge flowing through the cell will be CE.
(D) the amount of charge flowing through the cell will be 4/3 CE.



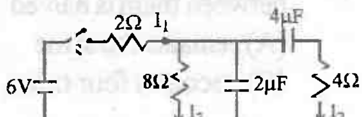
Q.4 In the circuit shown initially C_1, C_2 are uncharged. After closing the switch
(A) The charge on C_2 is greater that on C_1
(B) The charge on C_1 and C_2 are the same
(C) The potential drops across C_1 and C_2 are the same
(D) The potential drops across C_2 is greater than that across C_1



Q.5 A parallel plate air-core capacitor is connected across a source of constant potential difference. When a dielectric plate is introduced between the two plates then :
(A) some charge from the capacitor will flow back into the source.
(B) some extra charge from the source will flow back into the capacitor.
(C) the electric field intensity between the two plate does not change.
(D) the electric field intensity between the two plates will decrease.

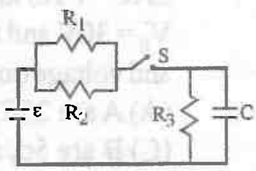
Q.6 A parallel plate capacitor has a parallel sheet of copper inserted between and parallel to the two plates, without touching the plates. The capacity of the capacitor after the introduction of the copper sheet is :
(A) minimum when the copper sheet touches one of the plates.
(B) maximum when the copper sheet touches one of the plates.
(C) invariant for all positions of the sheet between the plates.
(D) greater than that before introducing the sheet.

Q.7 In the circuit shown in the figure, the switch S is initially open and the capacitor is initially uncharged. I_1, I_2 and I_3 represent the current in the resistance 2Ω, 4Ω and 8Ω respectively.



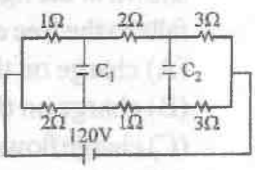
(A) Just after the switch S is closed, $I_1 = 3A$, $I_2 = 3A$ and $I_3 = 0$
(B) Just after the switch S is closed, $I_1 = 3A$, $I_2 = 0$ and $I_3 = 0$
(C) long time after the switch S is closed, $I_1 = 0.6\ A$, $I_2 = 0$ and $I_3 = 0$
(D) long after the switch S is closed, $I_1 = I_2 = I_3 = 0.6\ A$.

Q.8 The circuit shown in the figure consists of a battery of emf $\varepsilon = 10\ V$; a capacitor of capacitance $C = 1.0\ \mu F$ and three resistor of values $R_1 = 2\Omega$, $R_2 = 2\Omega$ and $R_3 = 1\Omega$. Initially the capacitor is completely uncharged and the switch S is open. The switch S is closed at $t = 0$.



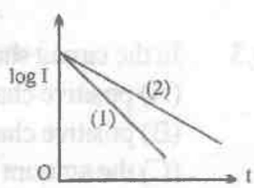
(A) The current through resistor R_3 at the moment the switch closed is zero.
(B) The current through resistor R_3 a long time after the switch closed is 5A.
(C) The ratio of current through R_1 and R_2 is always constant.
(D) The maximum charge on the capacitor during the operation is 5μC.

Q.9 In the circuit shown in figure $C_1 = C_2 = 2\mu F$. Then charge stored in



(A) capacitor C_1 is zero
(B) capacitor C_2 is zero
(C) both capacitor is zero
(D) capacitor C_1 is 40 μC

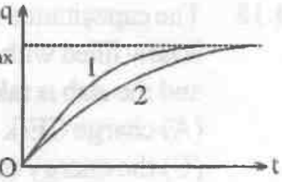
Q.10 A capacitor of capacity C is charged to a steady potential difference V and connected in series with an open key and a pure resistor 'R'. At time $t = 0$, the key is closed. If I = current at time t, a plot of log I against 't' is as shown in (1) in the graph. Later one of the parameters i.e. V, R or C is changed keeping the other two constant, and the graph (2) is recorded. Then



(A) C is reduced
(B) C is increased
(C) R is reduced
(D) R is increased

Question No.11 to 12 (2 questions)

The charge across the capacitor in two different RC circuits 1 and 2 are plotted as shown in figure.



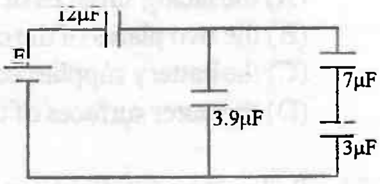
Q.11 Choose the correct statement(s) related to the two circuits.
(A) Both the capacitors are charged to the same charge.
(B) The emfs of cells in both the circuit are equal.
(C) The emf's of the cells may be different.
(D) The emf E_1 is more than E_2

Q.12 Identify the correct statement(s) related to the R_1, R_2, C_1 and C_2 of the two RC circuits.
(A) $R_1 > R_2$ if $E_1 = E_2$ (B) $C_1 < C_2$ if $E_1 = E_2$
(C) $R_1C_1 > R_2C_2$ (D) $\frac{R_1}{R_2} < \frac{C_2}{C_1}$

Q.13 A parallel plate capacitor is charged by connecting it to a battery. The battery is disconnected and the plates of the capacitor are pulled apart to make the separation between the plates twice. Again the capacitor is connected to the battery (with same polarity) then
(A) Charge from the battery flows into the capacitor after reconnection
(B) Charge from capacitor flows into the battery after reconnection.
(C) The potential difference between the plates increases when the plates are pulled apart.
(D) After reconnection of battery potential difference between the plate will immediately becomes half of the initial potential difference. (Just after disconnecting the battery)

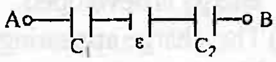
Q.14 The plates of a parallel plate capacitor with no dielectric are connected to a voltage source. Now a dielectric of dielectric constant K is inserted to fill the whole space between the plates with voltage source remaining connected to the capacitor.
(A) the energy stored in the capacitor will become K–times
(B) the electric field inside the capacitor will decrease to K–times
(C) the force of attraction between the plates will increase to K^2–times
(D) the charge on the capacitor will increase to K–times

Q.15 Four capacitors and a battery are connected as shown. The potential drop across the 7 μF capacitor is 6 V. Then the :



(A) potential difference across the 3 μF capacitor is 10 V
(B) charge on the 3 μF capacitor is 42 μC
(C) e.m.f. of the battery is 30 V
(D) potential difference across the 12 μF capacitor is 10 V.

Q.16 A circuit shown in the figure consists of a battery of emf 10 V and two capacitance C_1 and C_2 of capacitances 1.0 μF and 2.0 μF respectively. The potential difference $V_A - V_B$ is 5V



(A) charge on capacitor C_1 is equal to charge on capacitor C_2
(B) Voltage across capacitor C_1 is 5V.
(C) Voltage across capacitor C_2 is 10 V
(D) Energy stored in capacitor C_1 is two times the energy stored in capacitor C_2.

Q.17 A capacitor C is charged to a potential difference V and battery is disconnected. Now if the capacitor plates are brought close slowly by some distance :
(A) some +ve work is done by external agent (B) energy of capacitor will decrease
(C) energy of capacitor will increase (D) none of the above

Q.18 The capacitance of a parallel plate capacitor is C when the region between the plate has air. This region is now filled with a dielectric slab of dielectric constant k. The capacitor is connected to a cell of emf E, and the slab is taken out

(A) charge CE(k – 1) flows through the cell (B) energy $E^2C(k-1)$ is absorbed by the cell.

(C) the energy stored in the capacitor is reduced by $E^2C(k-1)$

(D) the external agent has to do $\frac{1}{2}E^2C(k-1)$ amount of work to take the slab out.

Q.19 Two capacitors of capacitances 1μF and 3μF are charged to the same voltages 5V. They are connected in parallel with oppositely charged plates connected together. Then:

(A) Final common voltage will be 5V. (B) Final common voltage will be 2.5 V

(C) Heat produced in the circuit will be zero. (D) Heat produced in the circuit will be 37.5 μJ

Q.20 The two plates X and Y of a parallel plate capacitor of capacitance C are given a charge of amount Q each. X is now joined to the positive terminal and Y to the negative terminal of a cell of emf E = Q/C.

(A) Charge of amount Q will flow from the negative terminal to the positive terminal of the cell inside it.

(B) The total charge on the plate X will be 2Q.

(C) The total charge on the plate Y will be zero.

(D) The cell will supply CE^2 amount of energy.

Q.21 A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities will remain the same?

(A) the electric field in the capacitor (B) the charge on the capacitor

(C) the potential difference between the plates (D) the stored energy in the capacitor.

Q.22 The separation between the plates of a isolated charged parallel plate capacitor is increased. Which of the following quantities will change?

(A) charge on the capacitor (B) potential difference across the capacitor

(C) energy of the capacitor (D) energy density between the plates.

Q.23 Each plate of a parallel plate capacitor has a charge q on it. The capacitor is now connected to a battery. Now,

(A) the facing surfaces of the capacitor have equal and opposite charges.

(B) the two plates of the capacitor have equal and opposite charges.

(C) the battery supplies equal and opposite charges to the two plates.

(D) the outer surfaces of the plates have equal charges.

Q.24 Following operations can be performed on a capacitor :

X – connect the capacitor to a battery of emf E. Y – disconnect the battery

Z – reconnect the battery with polarity reversed. W – insert a dielectric slab in the capacitor

(A) In XYZ (perform X, then Y, then Z) the stored electric energy remains unchanged and no thermal energy is developed.

(B) The charge appearing on the capacitor is greater after the action XWY than after the action XYW.

(C) The electric energy stored in the capacitor is greater after the action WXY than after the action XYW.

(D) The electric field in the capacitor after the action XW is the same as that after WX.

Q.25 A parallel plate capacitor is charged and then disconnected from the source of potential difference. If the plates of the condenser are then moved farther apart by the use of insulated handle, which one of the following is true?

(A) the charge on the capacitor increases (B) the charge on the capacitor decreases

(C) the capacitance of the capacitor increases (D) the potential difference across the plate increases

Q.26 A parallel plate capacitor is charged and then disconnected from the source steady E.M.F. The plates are then drawn apart farther. Again it is connected to the same source. Then :
(A) the potential difference across the plate increases, while the plates are being drawn apart.
(B) the charge from the capacitor flows into the source, when the capacitor is reconnected.
(C) more charge is drawn to the capacitor from the source, during the reconnection.
(D) the electric intensity between the plates remains constant during the drawing apart of plates.

Q.27 When a parallel plates capacitor is connected to a source of constant potential difference,
(A) all the charge drawn from the source is stored in the capacitor.
(B) all the energy drawn from the source is stored in the capacitor.
(C) the potential difference across the capacitor grows very rapidly initially and this rate decreases to zero eventually.
(D) the capacity of the capacitor increases with the increase of the charge in the capacitor.

Q.28 When two identical capacitors are charged individually to different potentials and connected parallel to each other, after disconnecting them from the source :
(A) net charge on connected plates is less than the sum of initial individual charges.
(B) net charge on connected plates equals the sum of initial charges.
(C) the net potential difference across them is different from the sum of the individual initial potential differences.
(D) the net energy stored in the two capacitors is less than the sum of the initial individual energies.

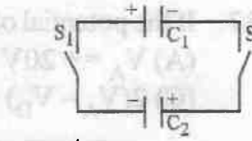
Q.29 A parallel plate capacitor of plate area A and plate seperation d is charged to potential difference V and then the battery is disconnected. A slab of dielectric constant K is then inserted between the plates of the capacitor so as to fill the space between the plates. If Q, E and W denote respectively, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted) and the work done on the system, in question, in the process of inserting the slab, then

(A) $Q = \frac{\varepsilon_0 AV}{d}$ (B) $Q = \frac{\varepsilon_0 KAV}{d}$ (C) $E = \frac{V}{Kd}$ (D) $W = -\frac{\varepsilon_0 AV^2}{2d}\left(1-\frac{1}{K}\right)$

Q.30 A parallel plate capacitor is connected to a battery. The quantities charge, voltage, electric field and energy associated with the capacitor are given by Q_0, V_0, E_0 and U_0 respectively. A dielectric slab is introduced between plates of capacitor but battery is still in connection. The corresponding quantities now given by Q, V, E and U related to previous ones are
(A) $Q > Q_0$ (B) $V > V_0$ (C) $E > E_0$ (D) $U < U_0$

Q.31 A parallel-plate capacitor is connected to a cell. Its positive plate A and its negative plate B have charges +Q and –Q respectively. A third plate C, identical to A and B, with charge +Q, is now introduced midway between A and B, parallel to them. Which of the following are correct?
(A) The charge on the inner face of B is now $-\frac{3Q}{2}$
(B) There is no change in the potential difference between A and B.
(C) The potential difference between A and C is one-third of the potential difference between B and C.
(D) The charge on the inner face of A is now $Q/2$.

Q.32 Two capacitors $C_1 = 4\ \mu F$ and $C_2 = 2\mu F$ are charged to same potential V = 500 Volt, but with opposite polarity as shown in the figure. The switches S_1 and S_2 are closed.

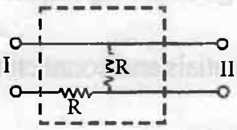


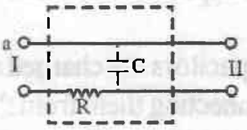
(A) The potential difference across the two capacitors are same and is given by $500/3$ V
(B) The potential difference across the two capacitors are same and is given by $1000/3$ V
(C) The ratio of final energy to initial energy of the system is 1/9.
(D) The ratio of final energy to initial energy of the system is 4/9.

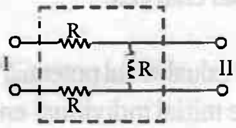
Q.33 A parallel plate capacitor is charged to a certain potential and the charging battery is then disconnected. Now, if the plates of the capacitor are moved apart then:
(A) The stored energy of the capacitor increases
(B) Charge on the capacitor increases
(C) Voltage of the capacitor decreases
(D) The capacitance increases

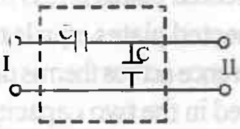
Q.34 If a battery of voltage V is connected across terminals I of the block box shown in figure, an ideal voltmeter connected to terminals II gives a reading of V/2, while if the battery is connected to terminals II, a voltmeter across terminals
I reads V. The black box may contain



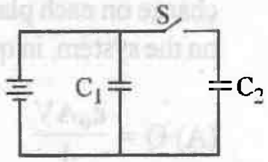
(A) 

(B) 

(C) 

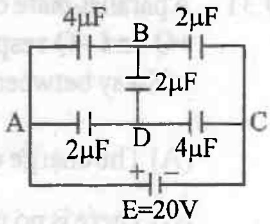
(D) 

Q.35 Two capacitors of equal capacitance ($C_1 = C_2$) are shown in the figure. Initially, while the switch S is open, one of the capacitors is uncharged and the other carries charge Q_0. The energy stored in the charged capacitor is U_0. Sometimes after the switch is closed, the capacitors C_1 and C_2 carry charges Q_1 and Q_2, respectively; the voltages across the capacitors are V_1 and V_2; and the energies stored in the capacitors are U_1 and U_2. Which of the following statements is INCORRECT ?



(A) $Q_0 = \frac{1}{2}(Q_1 + Q_2)$ (B) $Q_1 = Q_2$
(C) $V_1 = V_2$ (D) $U_1 = U_2$
(E) $U_0 = U_1 + U_2$

Question No.36 to 39 (4 questions)
The figure shows a diagonal symmetric arrangement of capacitors and a battery

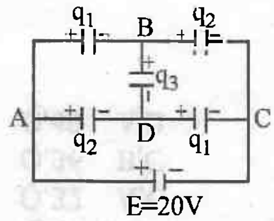


Q.36 Identify the correct statements.
(A) Both the 4μF capacitors carry equal charges in opposite sense.
(B) Both the 4μF capacitors carry equal charges in same sense.
(C) $V_B - V_D > 0$
(D) $V_D - V_B > 0$

Q.37 If the potential of C is zero, then
(A) $V_A = +20V$ (B) $4(V_A - V_B) + 2(V_D - V_B) = 2V_B$
(C) $2(V_A - V_D) + 2(V_B - V_D) = 4V_D$ (D) $V_A = V_B + V_D$

Q.38 The potential of the point B and D are
(A) $V_B = 8V$ (B) $V_B = 12V$ (C) $V_D = 8V$ (D) $V_D = 12V$

Q.39 The value of charge q_1, q_2 and q_3 as shown in the figure are



(A) $q_1 = 32\ \mu C$; $q_2 = 24\ \mu C$; $q_3 = -8\ \mu C$
(B) $q_1 = 48\ \mu C$; $q_2 = 16\ \mu C$; $q_3 = +8\ \mu C$
(C) $q_1 = 32\ \mu C$; $q_2 = 24\ \mu C$; $q_3 = +8\ \mu C$
(D) $q_1 = 3\ \mu C$; $q_2 = 4\ \mu C$; $q_3 = +2\ \mu C$

Q.40 If Q is the charge on the plates of a capacitor of capacitance C, V the potential difference between the plates, A the area of each plate and d the distance between the plates, the force of attraction between the plates is

(A) $\frac{1}{2}\left(\frac{Q^2}{\varepsilon_0 A}\right)$ (B) $\frac{1}{2}\left(\frac{CV^2}{d}\right)$ (C) $\frac{1}{2}\left(\frac{CV^2}{A\varepsilon_0}\right)$ (D) $\frac{1}{4}\left(\frac{Q^2}{\pi\varepsilon_0 d^2}\right)$

ANSWER KEY

ONLY ONE OPTION IS CORRECT

Q.1	B	Q.2	A	Q.3	C	Q.4	A	Q.5	B	Q.6	A
Q.7	B	Q.8	C	Q.9	D	Q.10	A	Q.11	B	Q.12	D
Q.13	C	Q.14	A	Q.15	C	Q.16	C	Q.17	B	Q.18	B
Q.19	B	Q.20	B	Q.21	A	Q.22	C	Q.23	B	Q.24	B
Q.25	D	Q.26	B	Q.27	A	Q.28	A	Q.29	D	Q.30	B
Q.31	C	Q.32	D	Q.33	B	Q.34	C	Q.35	A	Q.36	B
Q.37	B	Q.38	B	Q.39	A	Q.40	D	Q.41	D	Q.42	C
Q.43	B	Q.44	D	Q.45	D	Q.46	B	Q.47	C	Q.48	C
Q.49	B	Q.50	D	Q.51	A	Q.52	B	Q.53	B	Q.54	C

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	B,C	Q.2	A,B,C	Q.3	A,D	Q.4	B
Q.5	B,C	Q.6	C,D	Q.7	B	Q.8	A,B,C,D
Q.9	B,D	Q.10	B	Q.11	A,C	Q.12	D
Q.13	B,C	Q.14	A,C,D	Q.15	B,C,D	Q.16	A,D
Q.17	B	Q.18	A,B,D	Q.19	B,D	Q.20	A,B,C,D
Q.21	B	Q.22	B,C	Q.23	A,C,D	Q.24	B,C,D
Q.25	D	Q.26	A,B,D	Q.27	A,C	Q.28	B,C,D
Q.29	A,C,D	Q.30	A	Q.31	A,B,C,D	Q.32	A,C
Q.33	A	Q.34	D	Q.35	E	Q.36	B,C
Q.37	A,B,C,D	Q.38	B,C	Q.39	C	Q.40	A,B

BANSAL CLASSES

CHEMISTRY

TARGET IIT JEE 2007

XI (P, Q, R, S)

IIT-JEE SCREENING 2006

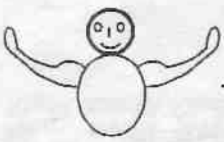
Raksha Bandhan

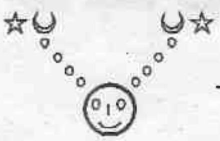
Holidays Assignment

This Question Bank will be discussed after the Rakshabandhan vacation.

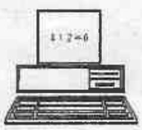
Time Limit : 2 Sitting Each of 60 Minutes duration approx.

FRIENDS FOR YOUR SELF ANALYSIS


⟶ ***Making your concepts stronger.***


⟶ ***Requires slight mind scratching.***


⟶ ***Requires recollection of various concepts.***


⟶ ***Requires calculation skill.***


⟶ ***Easy life.***

SITTING–I

(EASY LIFE)

Q.1 When an electronic transition occurs in an atom from higher energy state to a lower energy state with energy difference equal to ΔE electron volts, the wavelength of the radiation emitted is approximately equal to

(A) $\frac{12397\times10^{-10}}{\Delta E}$ cm (B) $\frac{12397\times10^{-10}}{\Delta E}$ Å (C) $\frac{12397\times10^{-10}}{\Delta E}$ m (D) $\frac{12397\times10^{10}}{\Delta E}$ cm

Q.2 In each of the following questions two statements are given as Assertion A and Reason R. Examine the statements carefully and answer the questions according to the instructions given below:
(A) if both **A** and **R** are correct and **R** is the correct reason of **A**.
(B) if both **A** and **R** are correct and **R** is not the correct reason of **A**.
(C) if **A** is correct and **R** is wrong.
(D) if **A** is wrong and **R** is correct.
(E) if both **A** and **R** are wrong.

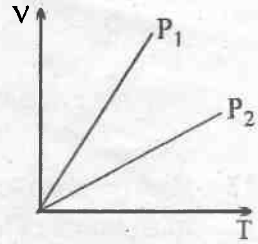
(a) **Assertion A.** The gases which are isosteres diffuse at the same rate under similar conditions.
Reason R. Diffusion and effusion do not follow the same law.

(b) **Assertion A.** The value of van der Waal constant b is higher for N_2 than for NH_3.
Reason R. NH_3 molecules are associated with H-bonds.

(c) **Assertion A.** K.E. of all the gases approach zero as their temperature approach zero kelvin.
Reason R. Molecular motion ceases at absolute zero.

(d) **Assertion A.** Helium shows only positive deviation from ideal behaviour.
Reason R. Helium is chemically inert noble gas.

Q.3 V vs T curves at differnt pressure P_1 and P_2 for an ideal gas are shown below. Which one of the following is correct?



(A) $P_1 > P_2$ (B) $P_1 < P_2$

(C) $P_1 = P_2$ (D) $\frac{P_2}{P_1} = \frac{1}{2}$

Q.4 The units of compressibility factor are
(A) atm L^{-1} (B) atm^{-1} (C) L^{-1} (D) unitless

Q.5 Which of the following statements is most appropriate for a real gas.
(A) Force of attraction between the molecules exists at low pressure only.
(B) Force of attraction between the molecules exists at high pressure only.
(C) Force of attraction between the molecules affect gaseous property at high temperature.
(D) Force of attraction between the molecules affect gaseous property at low pressure.

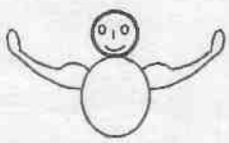
Q.6 Which among the following has rate of effusion less than the moist air?
(A) He (B) Dry air (C) NH_3 (D) Heavy hydrogen

Q.7 The behaviour of real gas is generally depicted by plotting which of the following parameter vs pressure
(A) critical volume (B) density (C) T_{ideal}/T_{real} (D) V_{real}/V_{ideal}

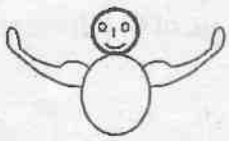
Q.8 The 'atom utilization' is obtained by dividing molar mass of the desired product by the sum of the molar masses of all substances produced according to the reaction equations. The "E factor" is the amount (in kg) of by product per kg of products. Calculate "atom utilization" and "E factor". Identify X, the desired product.
$(NH_4)_2S_2O_8 + MnSO_4 + 2H_2O \longrightarrow (NH_4)_2SO_4 + \underline{X} + 2H_2SO_4$

Q.9 Calculate molality of a solution containing 72 gm Buckminster Fullerene (C_{60}) in one kg water.

Q.10 The density of $CaCO_{3\,(s)}$ is 2.71 g/cm³. What is molarity of solid $CaCO_3$.



STRENGTHENING CONCEPTS



Q.11 If in the hydrogen atom P.E. at ∞ is chosen to be 13.6 eV then what would be P.E. & K.E. of e^- in the first Bohr orbit.

Q.12 The value of $(n_1 + n_2)$ and $(n_2^2 - n_1^2)$ for He^+ ion in atomic spectrum are 4 and 8 respectively. Identify the series and find $\bar{\nu}$ of corresponding line in emission sp.

BRAIN TEASERS

Q.13 For a polymerisation reaction involving gaseous reactant and product $A \rightleftharpoons nB$, 'A' undergoes polymerisation to an extent of 'α' as degree of polymerisation at a temp T_1. From this info calculate the following in terms of n and α.

(a) P_T/P_0 ratio where P_T is the pressure with the given extent of polymerisation and P_0 is the pressure before polymerisation when temperature was T_0 in a constant volume container

(b) V_T/V_0 ratio in a chamber where V_T is volume when polymerisation occurs and V_0 is before polymerisation. Both volume measured under similar condition of pressure & temperature.

(c) Vapour density of the mixture if the molecular weight of A is M_A.

(d) Compare rate of effusions before polymerisation and after the polymerisation.
assuming temp to be same & pressure = P_T & P_0 respectively,

RECALLING VARIOUS CONCEPTS AT ONE PLACE

Q.14 Calculate IE_8 of oxygen atom.

Q.15 Calculate percentage dissociation of H_2O into H^+ & OH^- at 298 K of a neutral water sample [pH = 7]

Q.16 A compound gave on analysis of 60 g sample 44.8 *l* of a gas at STP which turns lime water milky & other gas which increased the wt, of white. $CuSO_4$ crystal by 36 gm. Deduce the molecular formula of the compound.

Q.17 Elemental As, a poison that kills humans and animal pests may be obtained by reacting As_2O_3 with carbon to give As and CO. Compute masses of As and CO formed if 49.5 gm of As_2O_3 reacts completely with 7.20 gm of C. [Given at. wt. As = 75] ($CO + CO_2$)

CALCULATION SKILL

Q.18 Under identical experimental conditions which of the following pairs of gases will be the most easy to separate by using diffusion process

(A) H_2 and D_2
(B) $U^{235}F_6$ and $U^{238}F_6$
(C) CO_2 and C_3H_8
(D) O_2 and N_2

Q.19 A solution of palmitic acid (M = 256) in benzene contains 5 gm acid per litre. When this solution is dropped on surface, C_6H_6 gets evaporated and acid forms a unimolecular layer on the surface. If we wish to cover an area 5000 cm^2 with unimolecular film. What volume of solution in ml should be used? Area covered by one molecule of acid is 0.32 nm^2.

Q.20 105 ml of pure water at 4^0 C is saturated with NH_3 gas, producing a solution of density 0.9 gm/ml. If this solution contains 30% of NH_3 by wt., calculate its volume.

SITTING–II

EASY LIFE

Q.1 In each of the following questions two statements are given as Assertion A and Reason R. Examine the statements carefully and answer the questions according to the instructions given below:
(A) if both **A** and **R** are correct and **R** is the correct reason of **A**.
(B) if both **A** and **R** are correct and **R** is not the correct reason of **A**.
(C) if **A** is correct and **R** is wrong.
(D) if **A** is wrong and **R** is correct.
(E) if both **A** and **R** are wrong.

(a) **Assertion A.** α-particles have quite less penetrating power.
Reason R. α-particles are di-positive ions having appreciable mass.

(b) **Assertion A.** Isotopes of an element can be identified with the help of a mass spectrograph.
Reason R. A mass spectrograph can differentiate between ions having different charge to mass (e/m) ratio.

Q.2 If the mean free path is l at one bar pressure then its value at 5 bar pressure, if temperature is kept constant.

(A) $5\,l$ (B) $\frac{2}{5}l$ (C) $\frac{l}{5}$ (D) l.

Q.3 Open end manometer was connected to gas chanber. The Hg level stood 15 mm higher in the open end as compared to the end connected to gas chamber. If the atmospheric pressure is 101.3 kPa. The gas pressure in k Pa is
(A) 103.3 (B) 101.3 (C) 94.3 (D) 115.3

Q.4 Which of the following gas has highest value of 'a'?
(A) Ne (B) O_2 (C) Cl_2 (D) N_2

Q.5 Three gases of densities A (0.82), B (0.26), C (0.51) are enclosed in a vessel of 4L capacity. Pick up the correct statement assuming ideal gas behaviour:
I. Gas A will tend to lie at the bottom
II. The number of atoms of various gases A, B, C are same
III. The gases will diffuse to form homogeneous mixture
IV. The average kinetic energy of each gas is same
(A) I, IV (B) only III (C) III, IV (D) I, III

Q.6 Ratio of C_p and C_υ of a gas 'X' is 1.4. The number of atoms of the gas 'X' present in 11.2 litres of it at STP will be
(A) 6.02×10^{23} (B) 1.2×10^{23} (C) 3.01×10^{23} (D) 2.01×10^{23}

Q.7 The moles of O_2 required for reacting with 8960 mL g of ammonia at STP is
$xNH_3 + yO_2 \rightleftharpoons aNO + bH_2O$ is
(A) 5 (B) 2.5 (C) 1 (D) 0.5

Q.8 Find the number of spectral lines in Paschen series emitted by atomic H, when electron is excited from ground state to n^{th} energy level returns back.

BRAIN TEASERS

Q.9 For calculating lattice energy of an ionic crystal, the variation of potential energy was studied following the relation, $U(r) = -\dfrac{\alpha^2 e^2 nA}{r} + \dfrac{B}{r^x}$

where 'α', 'e', n, A and x are constants depending upon type of crystal and 'r' is the distance between the ions. Calculate expression of B in terms of given constant for a stable crystal lattice given that ions are at a distance of r_0. Calculate potential energy of the crystal in terms of r_0 and other given constants. Plot an appropriate graph of U (r) v/s r indicating r_0 in the graph.

Q.10 For a gaseous reaction ; $A_{(g)} \rightarrow B_{(g)} + 2C_{(g)}$, total pressure at various time from the start of reaction is studied. Complete the following table and calculate degreee of dissociation of A at time t = 50 min. Given that reaction is 40% complete at time t = 100 min. and 100% complete after a long time. What can be said about average of dissociate of A between 0 to 50 min & between 50 to 100 min. Can you give a possible reason for this.

Time	t = 0 min	t = 50 min.	t – 100 min.	t = ∞
$P_{(Total)}$	100 mm	150 mm	______	______
P_A	100 mm	______	______	______
P_B	______	______	______	______

where P_A and P_B are the partial pressures of A and B.

RECALLING VARIOUS CONCEPTS AT ONE PLACE

Q.11 A beam of some kind of particle of velocity 2.1×10^7 m/s is scattered by a gold (z = 79) foil. Find specific charge of this particle (charge/mass) if the distance of closest approach is 2.5×10^{-14} m.

Q.12 Show that for large value of principal Q. no. the frequency of an electron rotating in adjacent energy levels of H-atom and the radiant frequency for transition between these value all approach the same value.

Q.13 Find molality of mercurous ion, if the concentration of aqueous solution containing it is 160 ppm.

CALCULATION SKILL

Q.14 Which of the following gaves have mean free path longer than oxygen under similar conditions?
I. H_2 II. CO_2 III. Cl_2 IV. N_2
(A) I, III (B) II, IV (C) I, IV (D) II, III

Q.15 By what factor does water expand when converted into vapour at 100°C and 1 atm pressure. The density of liquid water at 100°C and 1 atm is 0.96 g cm^{-3}.
(A) 815 (B) 2000 (C) 1630 (D) 500

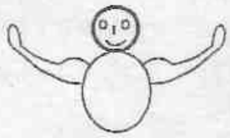
Q.16 The empirical formula of an organic compound containing carbon and hydrogen is CH_2. The mass of one litre of this organic gas is exactly equal to that of one litre of N_2. Therefore the molecular formula of the organic gas is

(A) C_2H_4 (B) C_3H_6 (C) C_6H_{12} (D) C_4H_8

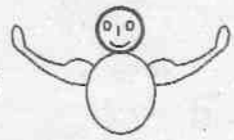
Q.17 In a photoelectric experiment, it was found that the stopping potential decreases from 1.85 V to 0.82V as the λ of incident light is varied from 300 nm to 400 nm. Calculate planks constant in eVs.

Q.18 0.015 mol $K_2Cr_2O_7$ oxidises 2.18 gm of a mix of XO and X_2O_3 into XO_4^- in acidic medium. If 0.0187 mol of XO_4 are formed. Calculate atomic weight of X.

$$6XO + 5Cr_2O_7^{2-} + 24H^+ \rightarrow 6XO_4^- + 10Cr^{3+} + 17H_2O$$
$$3X_2O_3 + 4Cr_2O_7^{2-} + 26H^+ \rightarrow 6XO_4^- + 8Cr^{3+} + 13H_2O$$



STRENGTHENING CONCEPTS



Q.19 Near Mount Kailash is the sacred lake, Mansorvar. In the crystal clear water of the lake, things at the bottom of the lake are also clearly visible. On a hot sunny day, when the temperature at the surface is 27°C an algae at the bottom of the lake produces a 25 ml bubble of pure oxygen. As the bubble rises to the top, it gets saturated with the water vapours and has a volume of 100 ml of the surface. The pressure at the surface is 720 mm Hg. If the depth of the lake is 27.2 m, find the temperature at the bottom of the lake. Vapour pressure of water at 27°C is 20 mm Hg. $d_{H_2O} = 1$ gm/ml, $d_{Hg} = 13.6$ g/ml.

Q.20 A beam of light has three λ, 4144 Å, 4972 Å and 6216 Å with a total intensity of 3.6×10^{-3} Wm^{-2} equally distributed amongst the three λ. The beam falls normally on an area 1.0 cm^2 of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection etc. Calculate the no. of photoelectrons emitted in 2 sec.

<u>JEE Humour</u>: A Physics teacher, a Maths teacher and a Chemistry teacher were walking on a sea shore. Fascinated by sea waves the physics teacher said, "I want to study the wave nature of sea waves" and went into the sea and never returned back. The maths teacher said, "I want to measure the volume of sea water" and went into the sea and never returned back. The chemistry teacher
concluded "Both physics and maths teacher are *soluble* in sea water under condition of 1 atm and 298 K.

ANSWER KEY

SITTING–I

Q.1	C	Q.2	(a) D, (b) B, (c) A, (d) B			Q.3	B
Q.4	D	Q.5	D	Q.6	B	Q.7	D
Q.8	0.13, 0.85	Q.9	0.1 m	Q.10	27.1 M		

Q.11 P.E = –13.6 eV, K.E. = 13.6 eV, T.E. = 0 eV

Q.12 $n_1 = 1, n_2 = 3$, $\bar{v} = 389969.7\ cm^{-1}$

Q.13 (a) $\frac{P_T}{P} = [1 + (n-1)\alpha] \times \frac{T_0}{T_1}$, (b) $\frac{V_T}{V} = [1 + (n-1)\alpha$, (c) $\left[\frac{M_A}{2}\left[\frac{1}{1+(n-1)\alpha}\right] = d\right]$

(d) $\frac{r_b}{r_a} = \frac{P}{P_T}\sqrt{\frac{1}{1+(n-1)\alpha}}$

Q.14	870 eV	Q.15	1.8×10^{-7} %	Q.16	CH_2O	Q.17	37.5, 19.2 grams
Q.18	A	Q.19	0.133 ml	Q.20	500/3		

SITTING–II

Q.1	(a) A, (b) A	Q.2	C	Q.3	A	Q.4	C
Q.5	C	Q.6	A	Q.7	D	Q.8	(n–4) (n–3)/2, n> 3

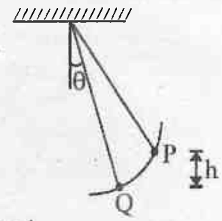
Q.9 $B = \frac{\alpha^2 e^2 n A r_0^{x-1}}{x}$ Q.10 25 % , 180, 300, 75, 60, 0, 0, 25, 40, 100

Q.11	4.8×10^7 C/g	Q.13	4×10^{-4} m	Q.14	~~A~~ C	Q.15	~~A~~ C
Q.16	A	Q.17	4.12×10^{-15} eVs			Q.18	99
Q.19	298.6 K	Q.20	11×10^{11}				

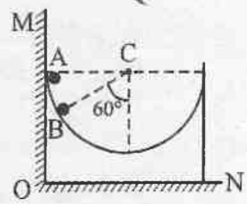
(CIRCULAR MOTION & WORK POWER ENERGY)

EXERCISE–I

Q.1 The bob of a simple pendulum of length l is released from point P. What is the angle made by the net acceleration of the bob with the string at point Q.

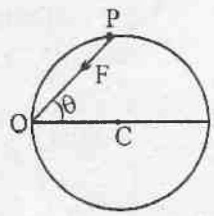


Q.2 A ball of mass 1 kg is released from position A inside a wedge with a hemispherical cut of radius 0.5 m as shown in the figure. Find the force exerted by the vertical wall OM on wedge, when the ball is in position B. (neglect friction everywhere). Take ($g = 10\ m/s^2$)



Q.3 A particle P is moving on a circle under the action of only one force acting always towards fixed point O on the circumference. Find ratio of

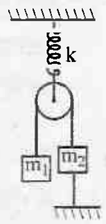
$$\frac{d^2\theta}{dt^2}\ \&\ \left(\frac{d\theta}{dt}\right)^2.$$



Q.4 A particle is moving in x direction, under the influence of force $F = \pi \sin \pi x$. Find the work done by another external agent in slowly moving a particle from $x = 0$ to $x = 0.5$ m.

Q.5 A particle moves in a circle of radius R with a constant speed v. Then, find the magnitude of average acceleration during a time interval $\frac{\pi R}{2v}$.

Q.6 In the figure shown, pulley and spring are ideal. Find the potential energy stored in the spring ($m_1 > m_2$).



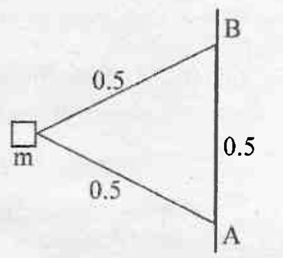
Q.7 A spring of mass m is pulled such that a given instant, velocity of both of its end is v in the opposite direction. Find the kinetic energy of the spring.



Q.8 A particle of mass 3 kg is rotating in a circle of radius 1 m such that the angle rotated by its radius is given by $\theta = 3\ (t + \sin t)$. Find the net force acting on the particle when $t = \pi/2$.

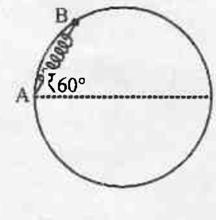
Q.9 For a particle rotating in a vertical circle with uniform speed, the maximum and minimum tension in the string are in the ratio 5 : 3. If the radius of vertical circle is 2m, then find the speed of revolving body.

Q.10 Two strings of length $l = 0.5$ m each are connected to a block of mass $m = 2$ kg at one end and their ends are attached to the point A and B 0.5 m apart on a vertical pole which rotates with a constant angular velocity $\omega = 7$ rad/sec. Find the ratio $\frac{T_1}{T_2}$ of tension in the upper string (T_1) and the lower string (T_2). [Use $g = 9.8\ m/s^2$]



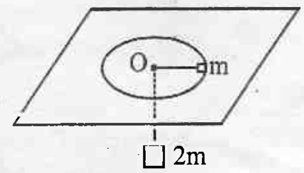
Q.11 A force $\vec{F} = -k(x\,\hat{i} + y\,\hat{j})$ [where k is a positive constant] acts on a particle moving in the x-y plane. Starting from origin, the particle is taken to (a, a) and then to $\left(a/\sqrt{2}, 0\right)$. Find the total work done by the force F on the particle.

Q.12 A bead of mass m is attached to one end of a spring of natural length $\sqrt{3}$ R and spring constant $k = \frac{(\sqrt{3}+1)\,mg}{R}$. The other end of the spring is fixed at point A on a smooth fixed vertical ring of radius R as shown in the figure. What is the normal reaction at B just after the bead is released?

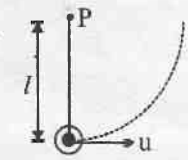


Q.13 Water is pumped from a depth of 10 m and delivered through a pipe of cross section 10^{-2} m^2 upto a height of 10 m. If it is needed to deliver a volume 0.2 m^3 per second, find the power required. [Use g = 10 m/s^2]

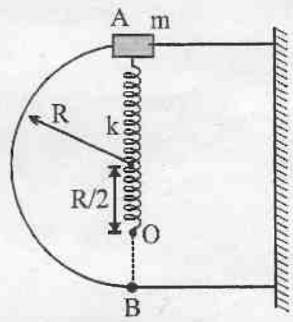
Q.14 A mass m rotating freely in a horizontal circle of radius 1 m on a frictionless smooth table supports a stationary mass 2m, attached to the other end of the string passing through smooth hole O in table, hanging vertically. Find the angular velocity of rotation.



Q.15 Consider the shown arrangement when a is bob of mass 'm' is suspended by means of a string connected to peg P. If the bob is given a horizontal velocity $\vec{u}$ having magnitude $\sqrt{3gl}$, find the minimum speed of the bob in subsequent motion.

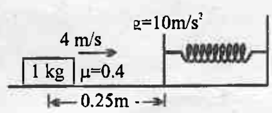


Q.16 A bead of mass m is tied at one end of a spring of spring constant $\frac{mg}{R}$ and unstretched length $\frac{R}{2}$ and other end to fixed point O. The smooth semicircular wire frame is fixed in vertical plane. Find the normal reaction between bead and wire just before it reaches the lowest point.



Q.17 A particle of mass m is hanging with the help of an elastic string of unstretched length a and force constant $\frac{mg}{a}$. The other end is fixed to a peg on vertical wall. String is given an additional extension of $2a$ in vertical downward direction by pulling the mass and released from rest. Find the maximum height reached by it during its subsequent motion above point of release. (Neglect interaction with peg if any)

Q.18 A particle of mass 1 kg is given a horizontal velocity of 4 m/s along a horizontal surface, with which it has a coefficient of friction (both static and kinetic) of 0.4. The particle strikes a fixed ideal spring of force constant 6 N/m after travelling a distance of 0.25 m. Assume acceleration due to gravity is 10 m/s^2. Find the final displacement of the particle from its starting point.

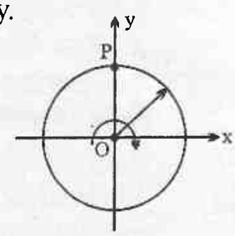


Q.19 A particle P of mass m is placed inside a hemispherical bowl which rotates about its vertical axis with constant angular velocity ω. The particle is just prevented from sliding down when the radius vector OP joining it to the centre of the bowl O makes an angle of 45^0 with the axis. The radius of the bowl is $10\sqrt{2}$ and the coefficient of friction between the particle and the bowl is 0.5. Find the value of angular velocity ω.

Q.20 A point moves along a circle having a radius 20 cm with a constant tangential acceleration 5 cm/s^2. How much time is needed after motion begins for the normal acceleration of the point to be equal to tangential acceleration ?

Q.21 A body of mass 2 kg is moving under the influence of a central force whose potential energy is given by $U(r) = 2r^3$ Joule. If the body is moving in a circular orbit of 5m, then find its energy.

Q.22 A ring rotates about z axis as shown in figure. The plane of rotation is xy. At a certain instant the acceleration of a particle P (shown in figure) on the ring is $(6\hat{i}-8\hat{j})$ m/s². find the angular acceleration of the ring & the angular velocity at that instant. Radius of the ring is 2m.



Q.23 A particle is revolving in a circle of radius 1m with an angular speed of 12 rad/s. At t = 0, it was subjected to a constant angular acceleration α and its angular speed increased to $(480/\pi)$ rpm in 2 sec. Particle then continues to move with attained speed. Calculate

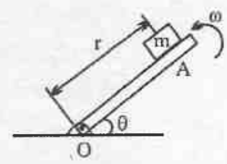
(a) angular acceleration of the particle,

(b) tangential velocity of the particle as a function of time.

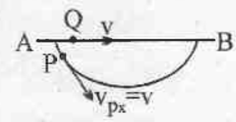
(c) acceleration of the particle at t = 0.5 second and at t = 3 second

(d) angular displacement at t = 3 second.

Q.24 The member OA rotates in vertical plane about a horizontal axis through O with a constant counter clockwise velocity $\omega = 3$ rad/sec. As it passes the position $\theta = 0$, a small mass m is placed upon it at a radial distance r = 0.5 m. If the mass is observed to slip at $\theta = 37°$, find the coefficient of friction between the mass & the member.



Q.25 A particle P is sliding down a frictionless hemispherical bowl. It passes the point A at t = 0. At this instant of time, the horizontal component of its velocity is v. A bead Q of the same mass as P is ejected from A at t=0 along the horizontal string AB, with the speed v. Friction between the bead and the string may be neglected. Which bead reaches point B earlier?



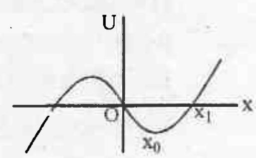
EXERCISE–II

Q.1 A particle is confined to move along the +x axis under the action of a force F(x) that is derivable from the potential $U(x) = ax^3 - bx$.

(a) Find the expression for F(x)

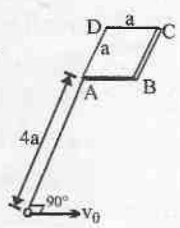
(b) When the total energy of the particle is zero, the particle can be trapped with in the interval $x = 0$ to $x = x_1$. For this case find the values of x_1.

(c) Determine the maximum kinetic energy that the trapped particle has in its motion. Express all answers in terms a and b.



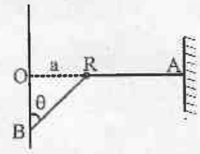
Q.2 A particle of mass 2kg is subjected to a two dimensional conservative force given by $F_x = -2x+2y$, $F_y = 2x-y^2$. (x,y in m and F in N) If the particle has kinetic energy of (8/3) J at point (2,3), find the speed of the particle when it reaches (1,2).

Q.3 A square plate is firmly atached to a frictionless horizontal plane. One end of a taut cord is attached to point A of the plate and the other end is attached to a sphere of mass m. In the process, the cord gets wrapped around the plate. The sphere is given an initial velocity v_0 on the horizontal plane perpendicular to the cord which causes it to make a complete circuit of the plate and return to point A. Find the velocity of the sphere when it hits point A again after moving in a circuit on the horizontal plane. Also find the time taken by the sphere to complete the circuit.



Q.4 A coin is placed on the horizontal surface of a rotating disc, If the disc starts from rest and is given a constant acceleration $\alpha = 1/\sqrt{2}$ rad/s², find the number of revolution through which the disc turns before the coin slips. The distance of coin from axis is 1 m initially and the coefficient of friction $\mu = 0.5$.

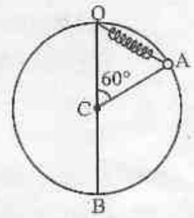
Q.5 A small bead of mass m is free to slide on a fixed smooth vertical wire, as indicated in the diagram. One end of a light elastic string, of unstretched length a and force constant 2mg/a is attached to B. The string passes through a smooth fixed ring R and the other end of the string is attached to the fixed point A, AR being horizontal. The point O on the wire is at same horizontal level as R, and AR = RO = a.



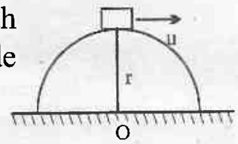
(i) In the equilibrium position, find OB.

(ii) The bead B is raised to a point C of the wire above O, where OC = a, and is released from rest. Find the speed of the bead as it passes O, and find the greatest depth below O of the bead in the subsequent motion.

Q.6 A particle of mass 5 kg is free to slide on a smooth ring of radius r = 20 cm fixed in a vertical plane. The particle is attached to one end of a spring whose other end is fixed to the top point O of the ring. Initially the particle is at rest at a point A of the ring such that $\angle OCA = 60°$, C being the centre of the ring. The natural length of the spring is also equal to r = 20cm. After the particle is released and slides down the ring the contact force between the particle & the ring becomes zero when it reaches the lowest position B. Determine the force constant of the spring.



Q.7 A small block of mass m is projected horizontally from the top of the smooth hemisphere of radius r with speed u as shown. For values of $u > u_0$, it does not slide on the hemisphere (i.e. leaves the surface at the top itself).

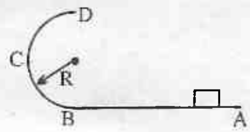


(a) For $u = 2u_0$, it lands at point P on ground Find OP.

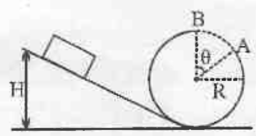
(b) For $u = u_0/3$, Find the height from the ground at which it leaves the hemisphere.

(c) Find its net acceleration at the instant it leaves the hemisphere.

Q.8 The track in Fig is straight in the horizontal section AB and is a semicircle of radius R in the vertical part BCD. A particle of mass m is given a velocity of $\sqrt{(22gR)/5}$ to the left along the track. The particle moves up the vertical section and ultimately loses contact with it. How far from point B will the mass land.

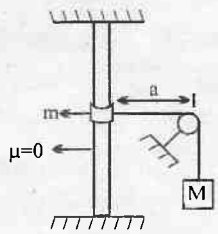


Q.9 A small particle of mass 1 kg slides without friction from height H = 45 cm shown in figure and then loops the vertical loop of radius R from where a section of angle $\theta = 60°$ has been removed. Find R such that after losing contact at A and flying through the air, the particle will reach at the point B. Also find the normal reaction between particle and path at A.

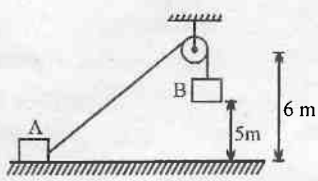


Q.10 A ring of mass m slides on a smooth vertical rod. A light string is attached to the ring and is passing over a smooth peg distant a from the rod, and at the other end of the string is a mass M (> m). The ring is held on a level with the peg and released : Show that it first comes to rest after falling a distance:

$$\frac{2mMa}{M^2 - m^2}$$



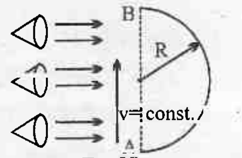
Q.11 A block of mass m is held at rest on a smooth horizontal floor. A light frictionless, small pulley is fixed at a height of 6 m from the floor. A light inextensible string of length 16 m, connected with A passes over the pulley and another identical block B is hung from the string. Initial height of B is 5m from the floor as shown in Fig. When the system is released from rest, B starts to move vertically downwards and A slides on the floor towards right.



(i) If at an instant string makes an angle θ with horizontal, calculate relation between velocity u of A and v of B.

(ii) Calculate v when B strikes the floor.

Q.12 A small block can move in a straight horizontal linea along AB. Flash lights from one side projects its shadow on a vertical wall which has horizontal cross section as a circle. Find tangential & normal acceleration of shadow of the block on the wall as a function of time if the velocity of the block is constant (v).



Top View

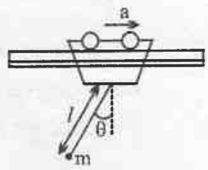
Q.13 In fig two identical springs, each with a relaxed length of 50cm and a spring constant of 500N/m, are connected by a short cord of length 10cm. The upper string is attached to the ceiling, a box that weighs 100N hangs from the lower spring. Two additional cords, each 85cm long, are also tied to the assembly; they are limp (i.e. slack).



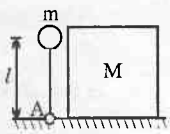
(a) If the short cord is cut, so that the box then hangs from the springs and the two longer cords, does the box move up or down?

(b) How far does the box move before coming to rest again?

Q.14 The small pendulum of mass m is suspended from a trolley that runs on a horizontal rail. The trolley and pendulum are initially at rest with $\theta = 0$. If the trolley is given a constant acceleration $a = g$ determine the maximum angle θ_{max} through which the pendulum swings. Also find the tension T in the cord in terms of θ.



Q.15 A weightless rod of length l with a small load of mass m at the end is hinged at point A as shown in the figure and occupies a strictly vertical position, touching a body of mass M. A light jerk sets the system in motion. For what mass ratio M/m will the rod form an angle $\alpha = \pi/6$ with the horizontal at the moment of the separation from the body? What will be the velocity u of the body at this moment? Friction should be neglected.



Q.16 The blocks are of mass 2 kg shown is in equilibrium. At t = 0 right spring in fig (i) and right string in fig (ii) breaks. Find the ratio of instantaneous acceleration of blocks?

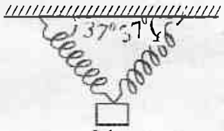


figure (i)

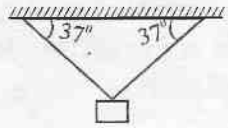
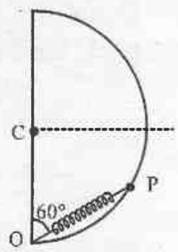


figure (ii)

EXERCISE–III

Q.1 A smooth semicircular wire track of radius R is fixed in a vertical plane. One end of a massless spring of natural length (3R/4) is attached to the lowest point O of the wire track. A small ring of mass m, which can slide on the track, is attached to the other end of the spring. The ring is held stationary at point P such that the spring makes an angle of 60° with the vertical. The spring constant K = mg/R. Consider the instant when the ring is released and



(i) draw the free body diagram of the ring.

(ii) determine the tangential acceleration of the ring and the normal reaction. [JEE 96]

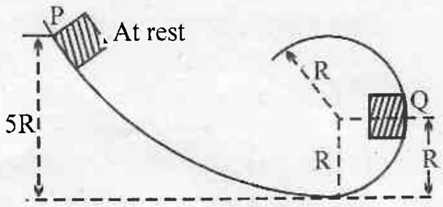
Q.2 Two blocks of mass m_1=10kg and m_2=5kg connected to each other by a massless inextensible string of length 0.3m are placed along a diameter of a turn table. The coefficient of friction between the table and m_1 is 0.5 while there is no friction between m_2 and the table. The table is rotating with an angular velocity of 10rad/sec about a vertical axis passing through its centre. The masses are placed along the diameter of the table on either side of the centre O such that m_1 is at a distance of 0.124m from O. The masses are observed to be at rest with respect to an observer on the turn table.

(i) Calculate the frictional force on m_1

(ii) What should be the minimum angular speed of the turn table so that the masses will slip from this position.

(iii) How should the masses be placed with the string remaining taut, so that there is no frictional force acting on the mass m_1. [JEE 97]

Q.3 A small block of mass m slides along a smooth frictional track as shown in the fig. (i) If it starts from rest at P, what is is the resultant force acting on it at Q? (ii) At what height above the bottom of the loop should the block be released so that the force it exerts against the track at the top of the loop equals its weight. [REE 97]



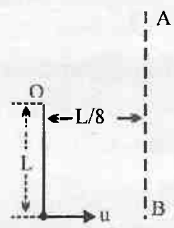
Q.4 A force $\vec{F} = -K(y\hat{i} + x\hat{j})$ where K is a positive constant, acts on a particle moving in the x-y plane. Starting from the origin, the particle is taken along the positive x-axis to the point (a,0) and then parallel to the y-axis to the pint (a,a). The total work done by the force $\vec{F}$ on the particle is [JEE 98]

(A) $-2Ka^2$ (B) $2Ka^2$ (C) $-Ka^2$ (D) Ka^2

Q.5 A stone is tied to a string of length l is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of the change in its velocity at it reaches a position where the string is horizontal is [JEE98]

(A) $\sqrt{(u^2 - 2gl)}$ (B) $\sqrt{2gl}$ (C) $\sqrt{(u^2 - gl)}$ (D) $\sqrt{2(u^2 - gl)}$

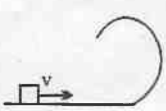
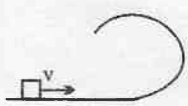
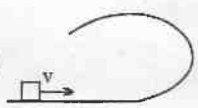
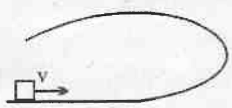
Q.6 A particle is suspended vertically from a point O by an inextensible massless string of length L. A vertical line AB is at a distance L/8 from O as shown. The object given a horizontal velocity u. At some point, its motion ceases to be circular and eventually the object passes through the line AB. At the instant of crossing AB, its velocity is horizontal. Find u. [JEE'99, 10]



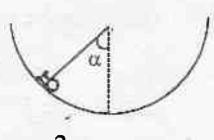
Q.7 A long horizontal rod has a bead which can slide along its length, and initially placed at a distance L from one end of A of the rod. The rod is set in angular motion about A with constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ and gravity is neglected, then the time after which the bead starts slipping is [JEE'2000]

(A) $\sqrt{\frac{\mu}{\alpha}}$ (B) $\frac{\mu}{\sqrt{\alpha}}$ (C) $\frac{1}{\sqrt{\mu\alpha}}$ (D) infinitesimal

Q.8 A small block is shot into each of the four tracks as shown below. Each of the tracks risks to the same height. The speed with which the block enters the track is the same in all cases. At the highest point of the track, the normal reaction is maximum in [JEE(Scr)'2001]

(A)  (B)  (C)  (D) 

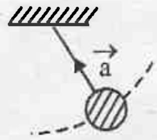
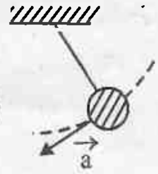
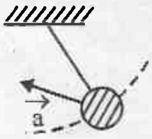
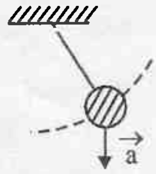
Q.9 An insect crawls up a hemispherical surface very slowly (see the figure). The coefficient of friction between the insect and the surface is 1/3. If the line joining the centre of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is given by [JEE(Scr.)'2001]



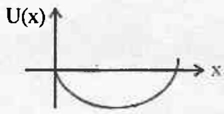
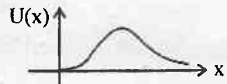
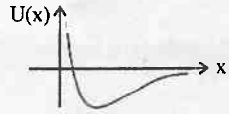
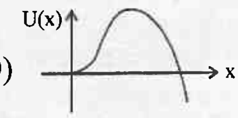
(A) cot α = 3 (B) tan α = 3 (C) sec α = 3 (D) cosec α = 3

Q.10 A small ball of mass $2x10^{-3}$ Kg having a charge of 1 μc is suspended by a string of length 0.8m. Another identical ball having the same charge is kept at the point of suspension. Determine the minimum horizontal velocity which should be imparted to the lower ball so that it can make complete revolution. [JEE'2001]

Q.11 A simple pendulum is oscillating without damping. When the displacement of the bob is less that maximum, its acceleration vector $\vec{a}$ is correctly shown in [JEE (Scr.)'2002]

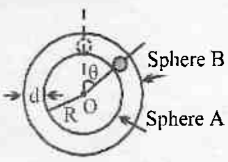
(A) 
(B) 
(C) 
(D) 

Q.12 A particle, which is constrained to move along the x-axis, is subjected to a force in the same direction which varies with the distance x of the particle x of the particle from the origin as $F(x) = -kx + ax^2$. Here k and a are positive constants. For $x \geq 0$, the functional form of the potential energy U (x) of the particle is [JEE (Scr.)'2002]

(A) 
(B) 
(C) 
(D) 

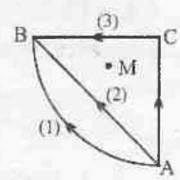
Q.13 An ideal spring with spring-constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is [JEE (Scr.)'2002]
(A) 4 Mg/k (B) 2 Mg/k (C) Mg/k (D) Mg/2k

Q.14 A spherical ball of mass m is kept at the highest point in the space between two fixed, concentric spheres A and B (see figure). The smaller sphere A has a radius R and the space between the two spheres has a width d. The ball has a diameter very slightly less than d. All surfaces are frictionless. The ball is given a gentle push (towards the right in the figure). The angle made by the radius vector of the ball with the upward vertical is denoted by θ (shown in the figure). [JEE' 2002]



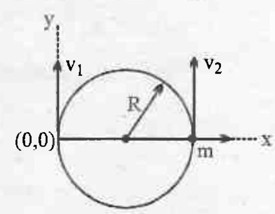
(a) Express the total normal reaction force exerted by the spheres on the ball as a function of angle θ.
(b) Let N_A and N_B denote the magnitudes of the normal reaction force on the ball exerted by the spheres A and B, respectively. Sketch the variations of N_A and N_B as functions of $\cos\theta$ in the range $0 \leq \theta \leq \pi$ by drawing two separate graphs in your answer book, taking $\cos\theta$ on the horizontal axes.

Q.15 In a region of only gravitational field of mass 'M' a particle is shifted from A to B via three different paths in the figure. The work done in different paths are W_1, W_2, W_3 respectively then [JEE (Scr.)'2003]

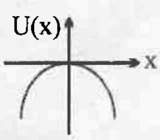
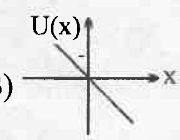
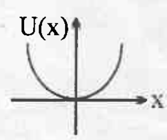
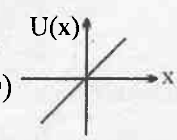


(A) $W_1 = W_2 = W_3$ (B) $W_1 = W_2 > W_3$
(C) $W_1 > W_2 > W_3$ (D) $W_1 < W_2 < W_3$

Q.16 A particle of mass m, moving in a circular path of radius R with a constant speed v_2 is located at point (2R, 0) at time t = 0 and a man starts moving with a velocity v_1 along the +ve y-axis from origin at time t = 0. Calculate the linear momentum of the particle w.r.t. the man as a function of time. [JEE' 2003]



Q.17 A particle is placed at the origin and a force F = kx is acting on it (where k is a positive constant). If U(0) = 0, the graph of U(x) versus x will be (where U is the potential energy function)

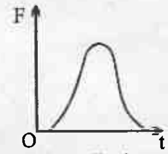
(A) 
(B) 
(C) 
(D) 

[JEE' 2004(Scr)]

CENTRE OF MASS MOMENTUM & COLLISION

The action of force with respect to time is defined in terms of Impulse, that is,

$$I = \int F dt = mv_f - mv_i = \Delta p$$



Graphically, impulse is the area under the F-t graph

In the absence of a net external force, the momentum of a system is conserved.

i.e. $$\frac{dP}{dt} = F_{ext} = 0$$

$$p = p_1 + p_2 + \ldots\ldots\ldots\ldots + p_N = \text{constant}$$

1. **Collision** is a kind of interaction between two or more bodies which come in contact with each other for a very short time interval.

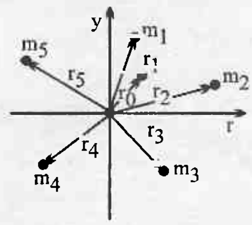
2. **Types of collision: Elastic and Inelastic**
Collisions may be either elastic or inelastic. Linear momentum is conserved in both cases.
(i) A perfectly elastic collision is defined as one in which the total kinetic energy of the system is conserved.
(ii) In an inelastic collision, the total kinetic energy of the system changes.
(iii) In a completely inelastic collision, the two bodies couple or stick togehter.

3. **Coefficient of Restitution :** It is defined as the ratio of the velocity of separation to the velocity of approach of the two colliding bodies.

$$e = \frac{\text{rel. velocity of separation}}{\text{rel. velocity of approach}}$$

For a perfectly elastic collision, $e = 1$
For an inelastic collision, $0 < e < 1$
For completely inelastic collision, $e = 0$
Note that the velocity of approach and the velocity of separation are always taken along the normal to the striking surface.

CENTRE OF MASS



1. **Discrete System :** The position vector of the centre of mass is

$$r_c = \frac{m_1 r_1 + m_2 r_2 + \ldots\ldots\ldots + m_n r_n}{m_1 + m_2 + \ldots\ldots\ldots m_n}$$

where $\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_n$ are the position vectors of masses $m_1, m_2, \ldots\ldots m_n$ respectively.
The components of the position vector of centre of mass are defined as

$$x_c = \frac{\sum m_i x_i}{M}; \qquad y_c = \frac{\sum m_i y_i}{M}; \qquad z_c = \frac{\sum m_i z_i}{M}$$

2. **Continuous system :** The centre of mass of a continuous body is defined as

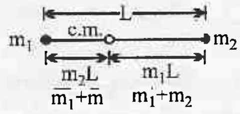
$$\vec{r}_c = \frac{1}{M}\int r\, dm$$

In the component form

$$x_c = \frac{1}{M}\int x\, dm; \qquad y_c = \frac{1}{M}\int y\, dm; \qquad z_c = \frac{1}{M}\int z\, dm$$

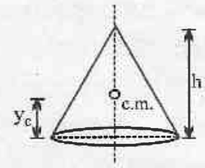
3. **Centre of Mass of Some Common Systems :**

(i) A system of two point masses.
The centre of mass lie closer to the heavier mass.



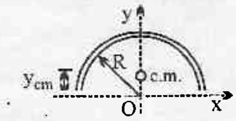
(ii) A circular cone

$$y_c = \frac{h}{4}$$



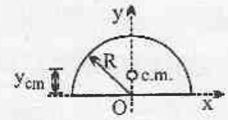
(iii) A semi-circular ring

$$y_c = \frac{2R}{\pi} \; ; \; x_c = 0$$



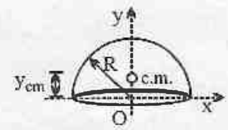
(iv) A semi-circular disc

$$y_c = \frac{4R}{3\pi} \; ; x_c = 0$$



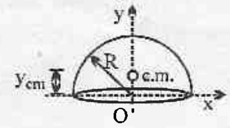
(v) A hemispherical shell

$$y_c = \frac{R}{2} \; ; x_c = 0$$



(vi) A solid hemisphere

$$y_c = \frac{3R}{8} \; ; x_c = 0$$



4. **Motion of the centre of mass :**

(i) **Velocity :** The instantaneous velocity of the centre of mass is defined as

$$v_c = \frac{\sum m_i v_i}{M}$$

(ii) **Acceleration :** The acceleration of the centre of mass is defined as

$$a_c = \frac{\sum m_i a_i}{M}$$

(iii) **Momentum :** The total momentum of a system of particles is

$$p = Mv_c$$

(iv) **Kinetic Energy :** The kinetic energy of a system of particles consisits of two parts.

$$K = K_c + K'$$

where $K_c = \frac{1}{2}Mv_c^2$, kinetic energy due to motion of c.m. relative to the fixed origin O,

and $K' = \sum \frac{1}{2} m_i v_i^2$, kinetic energy of the particles relative to the c.m.

Note that the term K' may involve translational, rotational or vibrational energies relative to the centre of mass.

5. **Newon's Laws of a system of particles :** The first and second laws of motion for a system of particles are modified as :

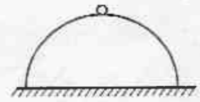
First law : The centre of mass of an isolated system is at rest or moves with constant velocity.

Second law : The net external force acting on a system of total of mass M is related to the acceleration of centre of mass of the system.

$$\sum \vec{F}_{ext} = M\vec{a}_{cm}$$

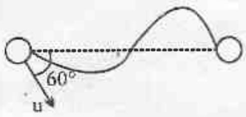
(CENTRE OF MASS MOMENTUM & COLLISION)
EXERCISE–I

Q.1 A hemisphere of radius R and of mass 4m is free to slide with its base on a smooth horizontal table. A particle of mass m is placed on the top of the hemisphere. Find the angular velocity of the particle relative to hemisphere at an angular displacement θ when velocity of hemisphere has become v.



Q.2 A man whose mass is m kg jumps vertically into air from a sitting position in which his centre of mass is at a height h_1 from the ground. When his feet are just about to leave the ground his centre of mass is h_2 from the ground and finally rises to h_3 when he is at the top of the jump. **(a)** What is the average upward force exerted by the ground on him? **(b)** Find work done by normal reaction from ground.

Q.3 In the figure shown, each tiny ball has mass m, and the string has length L. One of the ball is imparted a velocity u, in the position shown, in which the initial distance between the balls is $L/\sqrt{3}$. The motion of ball occurs on smooth horizontal plane. Find the impulse of the tension in the string when it becomes taut.

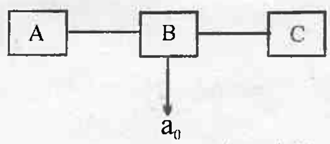


Q.4 Two trolleys A and B are free to move on a level frictionless track, and are initially stationary. A man on trolley A throws a bag of mass 10 kg with a horizontal velocity of 4 m/s with respect to himself on to trolley B of mass 100 kg. The combined mass of trolley A (excluding bag) and the man is 140 kg. Find the ratio of velocities of trolleys A and B, just after the bag lands on trolley B.

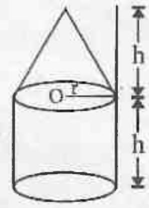
Q.5 A bob of mass m attached with a string of length l tied to a point on ceiling is released from a position when its string is horizontal. At the bottom most point of its motion, an identical mass m gently stuck to it. Find the angle from the vertical to which it rises.

Q.6 Two balls of equal masses are projected upward simultaneously, one from the ground with speed 50 m/s and other from a 40 m high tower with initial speed 30 m/s. Find the maximum height attained by their centre of mass.

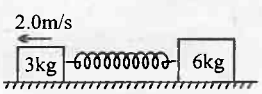
Q.7 3 blocks of mass 1kg each kept on horizontal smooth ground are connected by 2 taut strings of length l as shown. B is pulled with constant acceleration a_0 in direction shown. Find the relative velocity of A & C just before striking.



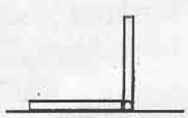
Q.8 Find the distance of centre of mass from O of a composite solid cone and solid cylinder made of same material.



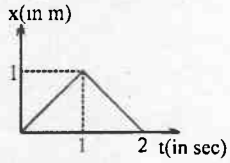
Q.9 Two blocks of mass 3 kg and 6 kg respectively are placed on a smooth horizontal surface. They are connected by a light spring. Initially the spring is unstretched and the velocity of 2 m/s is imparted to 3 kg block as shown. Find the maximum velocity of 6 kg block during subsequent motion.



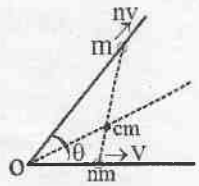
Q.10 Two planks each of mass m and length L are connected by a frictionless, massless hinge as shown in the figure. Initially the system is at rest on a level frictionless surface. The vertical plank falls anticlockwise and finaly comes to rest on the top of the horizontal plank. Find the displacement of the hinge till the two planks come in contact.



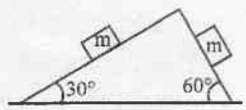
Q.11 2 bodies m_1 & m_2 of mass 1 and 2 kg respectively are moving along x-axis under the influence of mutual force only. The velocity of their centre of mass at a given instant is 2 m/s. The x coordinate of m_1 is plotted against time. Then plot the x coordinate of m_2 against time. (Both are initially located at origin)



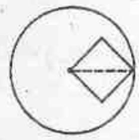
Q.12 Two masses, nm and m, start simultaneously from the intersection of two straight lines with velocities v and nv respectively. It is observed that the path of their centre of mass is a straight line bisecting the angle between the given straight lines. Find the magnitude of the velocity of centre of inertia.
(here θ = angle between the lines)



Q.13 Two blocks of equal masses m are released from the top of a smooth fixed wedge as shown in the figure. Find the magnitude of the acceleration of the centre of mass of the two blocks.



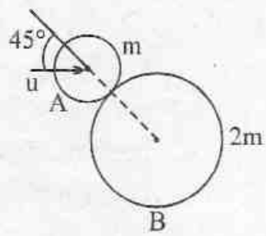
Q.14 From a uniform circular disc of radius R, a square is cut out with radius R as its diagonal. Find the centre of mass of remainder is at a distance.(from the centre)



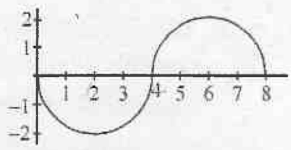
Q.15 A sphere of mass m_1 in motion hits directly another sphere of mass m_2 at rest and sticks to it, the total kinetic energy after collision is 2/3 of their total K.E. before collision. Find the ratio of $m_1 : m_2$.

Q.16 Two bodies of same mass tied with an inelastic string of length l lie together. One of them is projected vertically upwards with velocity $\sqrt{6gl}$. Find the maximum height up to which the centre of mass of system of the two masses rises.

Q.17 Disc A of mass m collides with stationary disk B of mass 2m as shown in figure. Find the value of coefficient of restitution for which the two disks move in perpendicular direction after collision.



Q.18 A force time (F – t) graph for linear motion is shown in the following figure. The segments shown are circular. Find the linear momentum gained between 4 and 8 second.(Assume S.I. units)



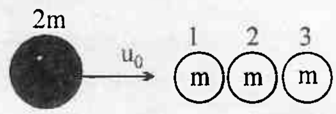
Q.19 A platform of mass m and a counter weight of mass (m + M) are connected by a light cord which passes over a smooth pulley. A man of mass M is standing on the platform which is at rest. If the man leaps vertically upwards with velocity u, find the distance through which the platform will descend. Show that when the man meets the platform again both are in their original positions.

Q.20 The figure shows the positions and velocities of two particles. If the particles move under the mutual attraction of each other, then find the position of centre of mass at t = 1 s.



Q.21 After scaling a wall of 3 m height a man of weight W drops himself to the ground. If his body comes to a complete stop 0.15 sec. After his feet touch the ground, calculate the average impulsive force in the vertical direction exerted by ground on his feet. ($g = 9.8 \text{ m/s}^2$)

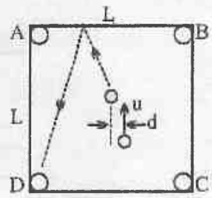
Q.22 A heavy ball of mass 2m moving with a velocity u_0 collides elastically head-on with a cradle of three identical balls each of mass m as shown in figure. Determine the velocity of each ball after collision.



EXERCISE–II

Q.1 A billiard table is 15 cm by 20 cm. A smooth ball of coefficient of restitution $e = 4/9$ is projected from a point on the shorter side so as to describe a rectangle and return to the point of projection after rebounding at each of the other three cushions. Find the position of the point and the direction of projection.

Q.2 In a game of Carom Board, the Queen (a wooden disc of radius 2 cm and mass 50 gm) is placed at the exact center of the horizontal board. The striker is a smooth plastic disc of radius 3 cm and mass 100 gm. The board is frictionless. The striker is given an initial velocity 'u' parallel to the sides BC or AD so that it hits the Queen inelastically with coefficient of restitution = 2/3. The impact parameter for the collision is 'd' (shown in the figure). The Queen rebounds from the edge AB of the board inelastically with same coefficient of restitution = 2/3 and enters the hole D following the dotted path shown. The side of the board is L.



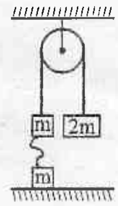
Find the value of impact parameter 'd' and the time which the Queen takes to enter hole D after collision with the striker.

Q.3 Two particles each of mass m are connected by a light inextensible string and a particle of mass M is attached to the midpoint of the string. The system is at rest on a smooth horizontal table with the string just taut and in a straight line. The particle M is given a velocity V along the table perpendicular to the string. Prove that when the two end particles are about to collide:

(a) the velocity of M is $\frac{MV}{(M+2m)}$

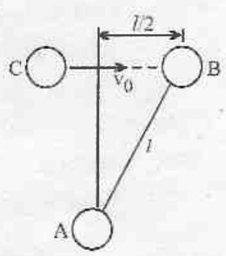
(b) the speed of each of the other particles is $\left(\frac{\sqrt{2M(M+m)}}{(M+2m)}\right)V$.

Q.4 The Atwood machine in fig has a third mass attached to it by a limp string. After being released, the 2m mass falls a distance x before the limp string becomes taut. Thereafter both the mass on the left rise at the same speed. What is the final speed ? Assume that pulley is ideal.

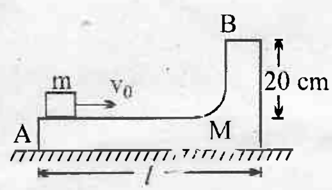


Q.5 Two scale pans, each of mass m, are connected by a light inelastic string which passes over a small smooth fixed light pulley. On one scale pan there is an inelastic particle A of mass 2m. The system is released from rest with the hanging parts of the string vertical. Find the tension in the string and the acceleration of either scale pan. At the instant when motion begins, a particle of mass 3m is allowed to fall from rest and after t seconds it strikes, and adheres to, A. Find the impulsive tension in the string and the velocity of either scale pan immediately after the impact.

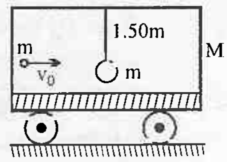
Q.6 Three spheres, each of mass m, can slide freely on a frictionless, horizontal surface. Spheres A and B are attached to an inextensible inelastic cord of length l and are at rest in the position shown when sphere B is struck directly by sphere C which is moving to the right with a velocity v_0. Knowing that the cord is taut when sphere B is struck by sphere C and assuming perfectly elastic impact between B and C, determine the velocity of each sphere immediately after impact.



Q.7 A wedge of mass M=2m rests on a smooth horizontal plane. A small block of mass m rests over it at left end A as shown in figure. A sharp impulse is applied on the block, due to which it starts moving to the right with velocity $v_0 = 6\ ms^{-1}$. At highest point of its trajectory, the block collides with a particle of same mass m moving vertically downwards with velocity $v = 2\ ms^{-1}$ and gets stuck with it. If the combined body lands at the end point A of body of mass M, calculate length l. Neglect friction ($g = 10\ ms^{-2}$)



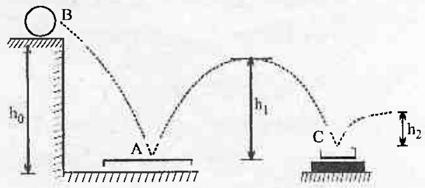
Q.8 A ball of mass = 1Kg is hung vertically by a thread of length $l = 1.50$ m. Upper end of the thread is attached to the ceiling of a trolley of mass M = 4 kg. Initially, trolley is stationary and it is free to move along horizontal rails without friction. A shell of mass m = 1 kg moving horizontally with velocity $v_0 = 6ms^{-1}$ collides with the ball and gets stuck with it. As a result, thread starts to deflect towards right. Calculate its maximum deflection with the vertical. ($g = 10m\,s^{-2}$)



Q.9 A 70g ball B droped from a height $h_0 = 9$ m reaches a height $h_2 = 0.25$m after bouncing twice from identical 210g plates. Plate A rests directly on hard ground, while plate C rests on a foam-rubber mat. Determine

(a) the coefficient of resitution between the ball and the plates,

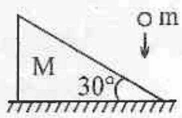
(b) the height h_1 of the ball's first bounce.



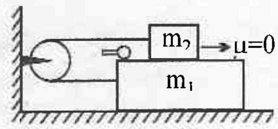
Q.10 A sphere of mass m is moving with a velocity $4\hat{i} - \hat{j}$ when it hits a smooth wall and rebounds with velocity $\hat{i} + 3\hat{j}$. Find the impulse it receives. Find also the coefficient of restitution between the sphere and the wall.

Q.11 A sphere A is of mass m and another sphere B of identical size but of mass 2m, move towards each other with velocity $\hat{i} + 2\hat{j}$ and $-\hat{i} + 3\hat{j}$ respectively. They collide when their line of centre is parallel to $\hat{i} - \hat{j}$. If e = 1/2, find the velocities of A and B after impact.

Q.12 A ball of mass m = 1 kg falling vertically with a velocity $v_0 = 2$ m/s strikes a wedge of mass M = 2kg kept on a smooth, horizontal surface as shown in figure. The coefficient of restitution between the ball and the wedge is e = 1/2. Find the velocity of the wedge and the ball immediately after collision.



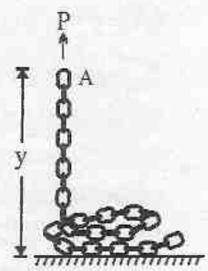
Q.13 A cannon is fixed on a plank of mass m_1 which is kept on smooth horizontal surface. On smooth surface of plank, a mass m_2 is kept as shown above. If shells of mass m each are fired from canon at the rate of N per second with velocity u relative to m_1, and the mass of shell is << mass m_1, find velocity of m_1 & m_2 as function of time.



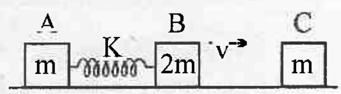
Q.14 A chain of length l and m lies in a pile on the floor. It its end A is raised vertically at a constant speed v_0, express in terms of the length y of chain which is off the floor at any given instant.

(a) the magnitude of the force P applied to end A.

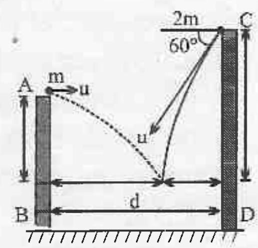
(b) the reaction of the floor. (c) energy lost during the lifting of the chain.



Q.15 Two blocks A and B of masses m and 2m respectively are connected by a spring of force constant k. The masses are moving to the right with uniform velocity v each, the heavier mass leading the lighter one. The spring in between them is of natural length during the motion. Block B collides with a third block C of mass m, at rest. The collision being completely inelastic. Calculate the maximum compression of the spring.



Q.16 Two towers AB and CD are situated a distance d apart as shown in fig. AB is 20 m high and CD is 30 m high from the ground. An object of mass m is thrown from the top of AB horizontally with a velocity 10 m/s towards CD. Simultaneously another object of mass 2m is thrown from the top of CD at an angle of 60° to the horizontal towards AB with the same magnitude of initial velocity as that of the first object. The two objects move in the same vertical plane, collide in mid air and stick to each other (a) Calculate the distance d between the towers and (b) find the position where the objects hit the ground?

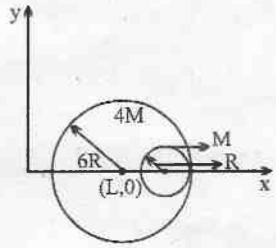


EXERCISE–III

Q.1 A set of n-identical cubical blocks lie at rest parallel to each other along a line on a smooth horizontal surface. The separation between the near surfaces of any two adjacent blocks is L. The block at one end is given a speed V towards the next one at time t = 0. All colisions are completely inelastic, then
(i) the last block starts moving at t = n(n – 1)L/(2v)
(ii) the last block starts moving at t = (n – 1)L/v
(iii) the centre of mass of the system will have a final speed v/n
(iv) the centre of mass of the system will have a final speed v. [IIT 95]

Q.2 A small bucket of mass M (=10^{-2}kg) is attached to a long cord of length L (= 5 × 10^{-2}m). The bucket is released from rest when the cord is in a horizontal position. In its lowest position the bucket scoops up m(=10^{-3}kg) of water, what is the height of the swing above the lowest position [REE 95]

Q.3 A small sphere of radius R is held against the inner surface of a larger sphere of radius 6R. The masses of large and small spheres are 4M and M respectively. This arrangement is placed on a horizontal table. There is no friction between any surfaces of contact. The small sphere is now released. Find the coordinates of the centre of the large sphere when the smaller sphere reaches the other extreme position. [IIT 96]



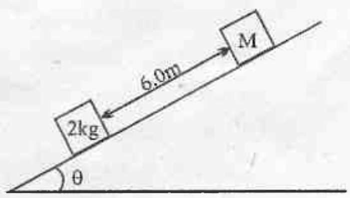
Q.4 A body of mass 5kg moves along the x axis with a velocity 2m/s. A second body of mass 10kg moves along the y axis with a velocity $\sqrt{3}$ m/s. They collide at the origin and stick together. Calculate
(i) the final velocity of the combined mass after collision
(ii) the amount of heat liberated in the collision. [REE 96]

Q.5 An isolated particle of mass m is moving in a horizontal plane (x-y) along the x-axis at a certain height above the ground. It suddenly explodes into two fragments of masses m/4 and 3m/4. An instant later the smaller fragment is at y = + 15 cm. The larger fragment at this instant is at [IIT 97]
(A) y = – 5cm (B) y = + 20cm (C) y = + 5cm (D) y = – 20cm

Q.6 A cart is moving along +x direction with a velocity of 4m/s. A person in the cart throws a stone with a velocity of 6m/s relative to himself. In the frame of reference of the cart the stone is thrown in y-z plane making an angle of 30° with the vertical z-axis. At the highest point of its trajectory, the stone hits an object of equal mass hung vertically from branch of a tree by means of a string of length L. A completely inelastic collision occurs, in which the stone gets embedded in the object. Determine
(a) the speed of the combined mass immediately after the collision with respect to an observer on the ground.
(b) the length L of the string such that the tension in the string becomes zero when the string becomes horizontal during the subsequent motion of the combined mass. [IIT 97]

Q.7 A particle of mass m and velocity v collides elastically and obliquely with a stationary particle of mass m. Calculate the angle between the velocity vectors of the two particles after the collision. [REE 97]

Q.8 Two blocks of mass 2kg and M are at rest on an indiclined plane and are separated by a distance of 6.0m as shown. The coefficient of friction between each of the blocks and the inclined plane is 0.25. The 2kg block is given a velocity of 10.0m/s up the inclined plane. It collides with M, comes back and has a velocity of 1.0m/s when it reaches its initial position. The other block M after the collision moves 0.5m up and comes to rest. Calculate the coefficient of restitution between the blocks and the mass of the block M. [Take sinθ ≈ tanθ = 0.05 and g = 10m/s²] [IIT 99]



Q.9 Two trolleys A and B of equal masses M are moving in oppsite directions with velocities $\vec{v}$ and $-\vec{v}$ respectively on separate horizontal frictionless parallel tracks. When they start crossing each other, a ball of mass m is thrown from B to A and another of same mass is thrown from A to B with velocities normal to $\vec{v}$. The balls may be thrown in following two ways:

(i) balls from A to B and B to A are thrown simultaneously.

(ii) ball is thrown from A to B after the ball thrown from B reaches A.

Which procedure would lead to a larger change in the velocities of the trolleys? [REE 2000]

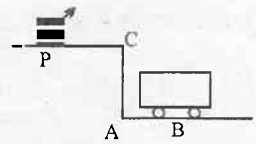
Q.10 A wind-powered generator converts wind energy into electrical energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to: [IIT (Scr) 2000]

(A) v (B) v^2 (C) v^3 (D) v^4

Q.11 Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1$ and $\vec{v}_2$ respectively at time t = 0. They collide at time t_0. Their velocities become $\vec{v}_1'$ and $\vec{v}_2'$ at time $2t_0$ while still moving in air. The value of $\left|(m_1\vec{v}_1' + m_2\vec{v}_2') - (m_1\vec{v}_1 + m_2\vec{v}_2)\right|$ is [IIT (Scr) 2001]

(A) zero (B) $(m_1 + m_2)gt_0$ (C) $2(m_1 + m_2)gt_0$ (D) $\frac{1}{2}(m_1 + m_2)gt_0$

Q.12 A car P is moving with a uniform speed of $5(3^{1/2})$ m/s towards a carriage of mass 9 Kg at rest kept on the rails at a point B as shown in fig. The height AC is 120 m. Cannon balls of 1 Kg are fired from the car with an initial velocity 100 m/s at an angle 30^0 with the horizontal. The first canon ball hits the stationary carriage after a time t_0 and sticks to it. Determine t_0. At t_0, the second cannon ball is fired. Assume that the resistive force between the rails and the carriage is constant and ignore the vertical motion of the carriage throughout. If the second ball also hits and sticks to the carriage. What will be the horizontal velocity of the carriage just after the second impact? [IIT 2001]



Q.13 Two block of masses 10 kg and 4 kg are connected by a spring of negligible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 14 m/s to the heavier block in the direction of the lighter block. The velocity of the centre of mass is : [IIT (Scr) 2002]

(A) 30 m/s (B) 20 m/s (C) 10 m/s (D) 5 m/s

ANSWER KEY
(NEWTONS LAW FORCE & FRICTION)
EXERCISE – I

Q.1 contact force between the block and the belt is 10.5 N   Q.2 35 kg

Q.3 306 N , 4.7 m/s^2

Q.4 2 sec   Q.5 $x_2 > x_1 > x_3$ $x_1 : x_2 : x_3 : 15 : 18 : 10$ Q.6 $\frac{1}{\sqrt{e}+1}$

Q.7 1 sec

Q.8 $\frac{100}{3}$ N towards left   Q.9 1 kg   Q.10 3 N   Q.11 $\left(\frac{m_1 - 2m_2}{2m_2}\right)g$

Q.12 12 N

Q.13 7.5 ms^{-2} Q.14 10/3 kg   Q.15 300 N   Q.16 55

Q.17 5   Q.18 2 sec   Q.19 $\frac{4}{3}$ sec   Q.20 $\frac{3}{4}$

Q.21 40 N   Q.22 $\tan^{-1}\left(\frac{1}{3\sqrt{3}}\right)$ Q.23 $\frac{a}{2}$ Q.24 1/2 sec   Q.25 5 sec and $\frac{1}{6}$ m

EXERCISE – II

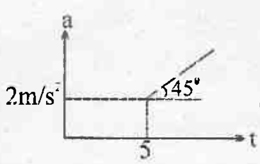
Q.1 (a) $a = g\cot\theta$, (b) $\mu_{min} = \frac{m\sin\theta\cos\theta}{m\cos^2\theta + M}$ Q.2 $\frac{3}{2\sqrt{2}}$

Q.3 $a_A = 12g/25$, $a_B = 9g/25$, $N = 12mg/25$

Q.4 (a) $a_A = \frac{3g\downarrow}{2} = a_B$; $a_C = 0$; $T = mg/2$; (b) $a_A = 2g\uparrow$, $a_B = 2g\downarrow$, $a_c = 0$, $T = 0$; (c) $a_A = a_B = g/2\uparrow$, $a_c = g\downarrow$, $T = \frac{3mg}{2}$; $T = 2mg$

Q.5 2g/23

Q.6 $T = \frac{15\times300}{32}$ N, $a = \frac{25}{32}$ m/s^2 Q.7 (a) $\eta = \frac{3}{5}$; (b) acceleration = 4 m/s^2

Q.8 (a) 

(b) 22.5 m/s ; (c) $\frac{275}{6}$ m; (d) $\sqrt{2}$ sec

Q.9 (a) (i) $a_1 = a_2 = 3.2$ m/s^2 , (ii) $a_1 = 5.75$ m/s^2 , $a_2 = 2$m/s^2 ; (b) $a_1 = 5$ m/s^2 , $a_2 = -10/3$ m/s^2

Q.10 (i)90N,(ii)112.5N(iii)150N   Q.11 $\mu_s = 0.4$, $\mu_k = 0.3$

Q.12 $\Delta r = \frac{mg\cot\alpha}{4\pi^2 k}$, 1cm   Q.13 $F = \frac{mg\pi}{2(1-\mu_K)}$

EXERCISE – III

Q.1 B   Q.2 (i) zero , (ii) can't be determined, (iii) can't be determined   Q.3 B

Q.4 (b) a = 3/5 m/s^2 , T = 18 N, F = 60N   Q.5 C   Q.6 D   Q.7 A

Q.8 11.313 m

(CIRCULAR MOTION & WORK POWER ENERGY)

EXERCISE – I

Q.1 $\tan^{-1}\left\{\frac{l\sin\theta}{2h}\right\}$ Q.2 $\frac{15\sqrt{3}}{2}$ N Q.3 $2\tan\theta$ Q.4 – 1 J

Q.5 $\frac{2\sqrt{2}\,v^2}{\pi R}$ Q.6 $\frac{2m_1^2g^2}{k}$ Q.7 $\frac{1}{6}mv^2$ Q.8 $9\sqrt{10}$ m/s^2

Q.9 $4\sqrt{5}$ m/s Q.10 9 Q.11 $-ka^2/4$ Q.12 $\left(1-\sqrt{3}/2\right)mg$

Q.13 80 kW Q.14 $\sqrt{2g}$ rad/s Q.15 $\frac{1}{3}\sqrt{\frac{gl}{3}}$ Q.16 6mg

Q.17 $9a/2$ Q.18 $\frac{7}{12}$m Q.19 $\frac{1}{\sqrt{3}}$ rad/s Q.20 2 sec

Q.21 625 J Q.22 $-3\hat{k}$ rad/s^2, $-2\hat{k}$ rad/s

Q.23 (a) 2 rad/s^2, (b) 12+2t for $t \le 2$s, 16 for $t \ge 2$s, (c) $\sqrt{28565} \simeq 169$, 256 m/s^2 (d) 44 rad

Q.24 0.1875 Q.25 P

EXERCISE – II

Q.1 $F = -3ax^2 + b$, $x = \sqrt{\frac{b}{a}}$, $KE_{max} = \frac{2b}{3\sqrt{3}}\sqrt{\frac{b}{a}}$ Q.2 2 m/s Q.3 $v = v_0$, $5\pi a/v_0$

Q.4 $N = \frac{1}{4\pi}\sqrt{(\mu g/r\alpha)^2 - 1} = \frac{7}{4\pi}$

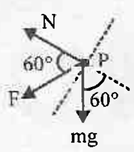
Q.5 (i) $\frac{a}{2}$, (ii) $2\sqrt{ag}$, 2a

Q.6 500N/m Q.7 (a) $2\sqrt{2}$ r, (b) $h = \frac{19r}{27}$, (c) g Q.8 1.19R Q.9 R = 0.2 m, 10 N

Q.11 $u = v\sec\theta$, $v = \frac{40}{\sqrt{41}}$ m/s Q.12 $a_N = \frac{vR}{(2Rt - vt^2)}$, $a_t = \frac{R(vt-R)v^{1/2}}{(2Rt-vt^2)^{3/2}}$

Q.13 up, 10cm Q.14 $\theta_{max}=\pi/2$, T=mg(3sinθ+3cosθ–2) Q.15 4, $\sqrt{gl/8}$ Q.16 $\frac{25}{24}$

EXERCISE – III

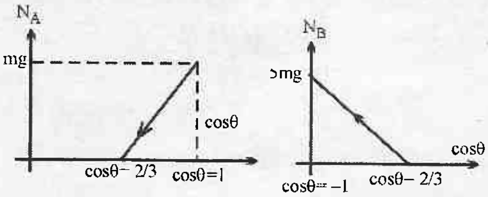
Q.1 

, $a_t = 5\sqrt{3}\,g/8$, N=3mg/8 Q.2 (i) 36N, (ii) 11.66rad/sec ,(iii) 0.1m, 0.2m

Q.3 F=-8mgi-mgj, h=3R Q.4 C Q.5 D Q.6 $u = \sqrt{gL\left(\frac{3\sqrt{3}}{2}+2\right)}$ Q.7 A

Q.8 A Q.9 A Q.10 5.79 m/s Q.11 C Q.12 D Q.13 B

Q.14 (a) $N = 3mg\cos\theta - 2mg$, (b)



Q.15 A

Q.16 $\vec{P}_{PM} = m\,\vec{v}_{PM} = -mv_2 \sin\omega t\,\hat{i} + m(v_2\cos\omega t - v_1)\,\hat{j}$

Q.17 A

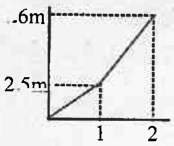
(CENTRE OF MASS & MOMENTUM)

EXERCISE – I

Q.1 $\frac{5v}{R\cos\theta}$ Q.2 (a) $\frac{mg(h_3 - h_2)}{(h_2 - h_1)}$; (b) 0 Q.3 $\frac{[mu\sqrt{3}]}{4}$ Q.4 11/14

Q.5 $\cos^{-1}(3/4)$ Q.6 100 m Q.7 $2\sqrt{2a_0 l}$ Q.8 $\frac{5h}{16}$ Q.9 4/3 m/s

Q.10 L/4 Q.11



Q.12 $\frac{2nv\cos(\theta/2)}{n+1}$ Q.13 g/2 Q.14 $\frac{R}{4\pi - 2}$ Q.15 2 : 1

Q.16 l Q.17 $\frac{1}{2}$ Q.18 + 2π N-s Q.19 $\frac{Mu^2}{2g(M+2m)}$ Q.20 x = 6m

Q.21 6.21 W Q.22 $v_{\text{heavy ball}} = \frac{u_0}{27}$, $v_{\text{first ball}} = \frac{4u_0}{27}$, $v_{\text{second ball}} = \frac{4u_0}{9}$, $v_{\text{third ball}} = \frac{4u_0}{3}$

EXERCISE – II

Q.1 $x = 3$ units, $\tan\theta = 2/3$

Q.2 $5/\sqrt{17}$ cm, 153L/80u Q.4 $\sqrt{\frac{3gx}{8}}$ Q.5 $\frac{3mg}{2}; \frac{g}{2}; \frac{3mgt}{14}; \frac{5gt}{7}$

Q.6 $v_c = -\frac{v_0}{15}$, $v_B = \frac{\sqrt{208}\,v_0}{15}$, $v_A = \frac{4v_0}{15}$

Q.7 40 cm Q.8 37^0 Q.9 (a) 0.66, (b) 4 m Q.10 impulse = $m(-3\hat{i} + 4\hat{j})$, $e = \frac{9}{16}$

Q.11 $\frac{1}{2}(-\hat{i} + 7\hat{j}), \frac{1}{4}(-\hat{i} + 9\hat{j})$ Q.12 $v_1 = \frac{1}{\sqrt{3}}$ m/s, $v_2 = \frac{2}{\sqrt{3}}$ m/s Q.13 $v = u\,ln\left[\frac{(m_1+m_2)}{m_1+m_2-Nmt}\right]$

Q.14 (a) $\frac{m}{l}(gy + v_0^2)$, (b) $mg\left(1 - \frac{y}{l}\right)$, (c) $\frac{mv_0^2 y}{2l}$ Q.15 $\sqrt{\frac{mv^2}{12k}}$ Q.16 (i) $10\sqrt{3}$, (ii) 11.54 from AB

EXERCISE – III

Q.1 (i), (iii) Q.2 4.13×10^{-2}m Q.3 (L + 2R, 0) Q.4 4/3 m/s, 35/3 J

Q.5 A Q.6 2.5 m, 0, 319 m Q.7 90°

Q.8 $e = \frac{5+\sqrt{3}}{8}$, $M = \frac{26}{\sqrt{3}}$ kg, Q.9 2 in case I Q.10 C Q.11 C

Q.12 $t_0 = 12$ sec, $v = \frac{100\sqrt{3}}{11}$ Q.13 C

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

CURRENT ELECTRICITY

QUESTION FOR SHORT ANSWER

Q.1 Fluorescent light bulbs are usually more efficient light emitters than incandescent bulbs. That is, for the same input energy, the fluorescent bulb gives off more light than the incandescent bulb. Carefully touch a fluorescent bulb and in an incandescent one after each has been lit for a few minutes. Explain why the incandesent bulb is a less efficient light emitter.

Q.2 Birds perch on high tension wires all the time. Why are they not electrocuted, even when they perch on a part of the wire where the insulation has worn off?

Q.3 Explain why touching an exposed circuit wire when you are in a damp basement is much more dangerous than touching the same wire when you are on the second floor.

Q.4 Initiallly, a single resistor R_1 is wired to a battery. Then resistor R_2 is added in parallel. Are (a) the potential difference across R_1 and (b) the current i_1 through R_1 now more than, less than, or the same as previously? (c) Is the equivalent resistance R_{12} of R_1 and R_2 more than, less than, or equal to R_1? (d) Is the total current through R_1 and R_2 together more than, less than, or equal to the current through R previously?

Q.5 A current enters the top of a copper sphere of radius R and leaves through the diametrically opposite point. are all parts equally effective in dissipating joule heat?

Q.6 How can an electric heater designed for 220 V be adopted for 110 V without changing the length of the coil and also without a change in the consumed power?

Q.7 The brilliance of lamps in a room noticeably drops as soon as a high power electric iron is switched on and after a short interval, the bulbs regain their original brilliance.Explain.

Q.8 Consider a circuit containing an ideal battery connected to a resistor. Do "work done by the battery" and " the thermal energy developed" represent two names of the same physical quantity?

Q.9 A current is passed through a steel wire which gets heated to a dull red. then half the wire is immersed in cold water. The portion out of the water becomes brighter. Why?

Q.10 A non ideal battery is connected to a resistor. Is work done by the battery equal to the thermal energy developed in the resistor? Does your answer change if the battery is ideal?

Q.11 For manual control of the current of a circuit, two rheostats in parallel are preferable to a single rheostat. Why?

Q.12 The drift velocity of electrons is quite small. How then does a bulb light up as soon as the switch is turned on, although the bulb may be quite far from the switch?

Q.13 Some times it is said that "heat is developed" in a resistance when there is an electric current in it. Recall that heat is defined as the energy being transferred due to the temperature difference. Is the statement under quotes technically correct?

Q.14 Does emf have electrostatic origin?

Q.15 The resistance of the human body is about 10 kΩ. If the resistance of our body is so large, why does one experience a strong shock from a live wire of 220 V supply ?

Q.16 Would you prefer a voltmeter or a potentiometer to measure the emf of a battery?

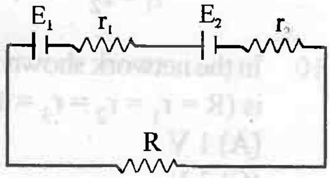
Q.17 Can the potential difference across a battery be greater than its emf?

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

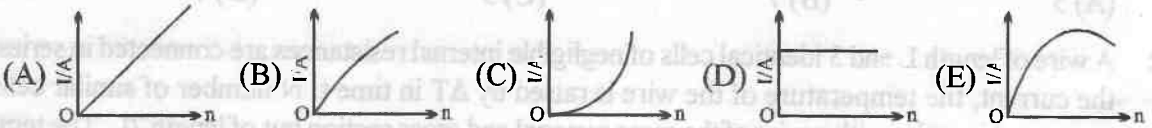
Q.1 A storage battery is connected to a charger for charging with a voltage of 12.5 Volts. The internal resistance of the storage battery is 1Ω. When the charging current is 0.5 A, the emf of the storage battery is:
(A) 13 Volts (B) 12.5 Volts (C) 12 Volts (D) 11.5 Volts

Q.2 Under what condition current passing through the resistance R can be increased by short circuiting the battery of emf E_2. The internal resistances of the two batteries are r_1 and r_2 respectively.

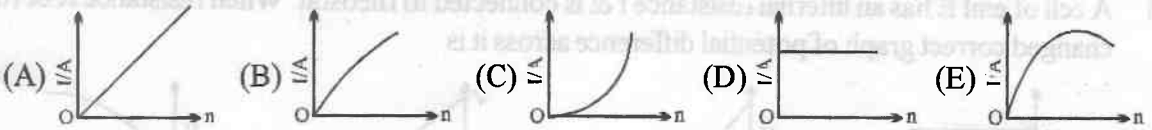


(A) $E_2r_1 > E_1(R + r_2)$ (B) $E_1r_2 > E_2(R + r_1)$
(C) $E_2r_2 > E_1(R + r_2)$ (D) $E_1r_1 > E_2(R + r_1)$

Q.3 A battery consists of a variable number n of identical cells having internal resistance connected in series. The terminals of the battery are short circuited and the current I measured. Which one of the graph below shows the relationship between I and n?



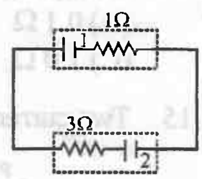
Q.4 In previous problem, if the cell had been connected in parallel (instead of in series) which of the above graphs would have shown the relationship between total current I and n?



Q.5 n identical cells are joined in series with its two cells A and B in the loop with reversed polarities. EMF of each shell is E and internal resistance r. Potential difference across cell A or B is (here n>4)

(A) $\frac{2E}{n}$ (B) $2E\left(1-\frac{1}{n}\right)$ (C) $\frac{4E}{n}$ (D) $2E\left(1-\frac{2}{n}\right)$

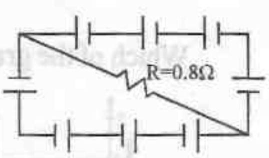
Q.6 In the figure shown, battery 1 has emf = 6 V and internal resistance = 1 Ω. Battery 2 has emf = 2V and internal resistance = 3 Ω. The wires have negligible resistance. What is the potential difference across the terminals of battery 2 ?



(A) 4 V (B) 1.5 V
(C) 5 V (D) 0.5 V

Q.7 The terminal voltage across a battery of emf E can be
(A) 0 (B) > E (C) < E (D) all of above

Q.8 A circuit is comprised of eight identical batteries and a resistor R = 0.8Ω. Each battery has an emf of 1.0 V and internal resistance of 0.2Ω. The voltage difference across any of the battery is

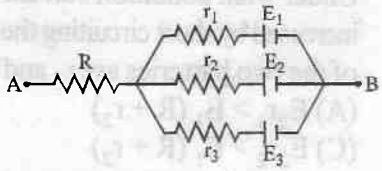


(A) 0.5V (B) 1.0V
(C) 0 V (D) 2 V

Q.9 In order to determine the e.m.f. of a storage battery it was connected in series with a standard cell in a certain circuit and a current I_1 was obtained. When the battery is connected to the same circuit opposite to the standard cell a current I_2 flow in the external circuit from the positive pole of the storage battery was obtained. What is the e.m.f. ε_1 of the storage battery? The e.m.f. of the standard cell is ε_2.

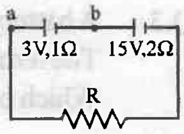
(A) $\varepsilon_1 = \frac{I_1 + I_2}{I_1 - I_2}\varepsilon_2$ (B) $\varepsilon_1 = \frac{I_1 + I_2}{I_2 - I_1}\varepsilon_2$ (C) $\varepsilon_1 = \frac{I_1 - I_2}{I_1 + I_2}\varepsilon_2$ (D) $\varepsilon_1 = \frac{I_2 - I_1}{I_1 + I_2}\varepsilon_2$

Q.10 In the network shown the potential difference between A and B is ($R = r_1 = r_2 = r_3 = 1\ \Omega$, $E_1 = 3$ V, $E_2 = 2$ V, $E_3 = 1$ V)



(A) 1 V (B) 2 V
(C) 3 V (D) 4 V

Q.11 Two batteries one of the emf 3V, internal resistance 1 ohm and the other of emf 15 V, internal resistance 2 ohm are connected in series with a resistance R as shown. If the potential difference between a and b is zero the resistance of R in ohm is

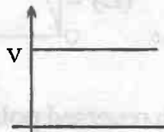


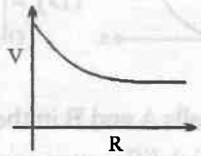
(A) 5 (B) 7 (C) 3 (D) 1

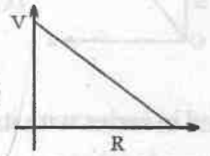
Q.12 A wire of length L and 3 identical cells of negligible internal resistances are connected in series. Due to the current, the temperature of the wire is raised by ΔT in time t. N number of similar cells is now connected in series with a wire of the same material and cross section but of length 2L. The temperature of the wire is raised by the same amount ΔT in the same time t. The value of N is :

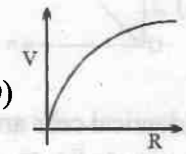
(A) 4 (B) 6 (C) 8 (D) 9

Q.13 A cell of emf E has an internal resistance r & is connected to rheostat. When resistance R of rheostat is changed correct graph of potential difference across it is

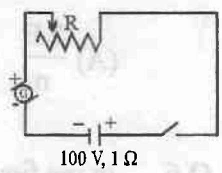
(A) 

(B) 

(C) 

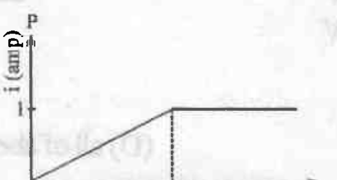
(D) 

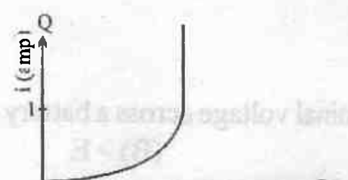
Q.14 The battery in the diagram is to be charged by the generator G. The generator has a terminal voltage of 120 volts when the charging current is 10 amperes. The battery has an emf of 100 volts and an internal resistance of 1 ohm. In order to charge the battery at 10 amperes charging current, the resistance R should be set at



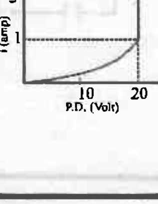
(A) 0.1 Ω (B) 0.5 Ω
(C) 1.0 Ω (D) 5.0 Ω

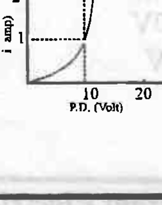
Q.15 Two current elements P and Q have current voltage characteristics as shown below :

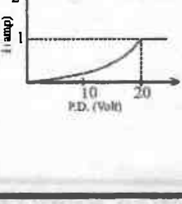


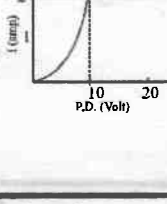


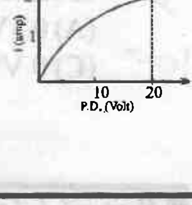
Which of the graphs given below represents current voltage characteristics when P and Q are in series.

(A) 

(B) 

(C) 

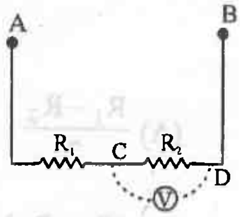
(D) 

(E) 

Q.16 A wire of cross-section area A, length L_1, resistivity ρ_1 and temperature coefficient of resistivity α_1 is connected to a second wire of length L_2, resistivity ρ_2, temperature coefficient of resistivity α_2 and the same area A, so that wire carries same current. Total resistance R is independent of temperature for small temperature change if (Thermal expansion effect is negligible)

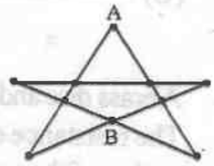
(A) $\alpha_1 = -\alpha_2$ (B) $\rho_1 L_1 \alpha_1 + \rho_2 L_2 \alpha_2 = 0$
(C) $L_1 \alpha_1 + L_2 \alpha_2 = 0$ (D) None

Q.17 Resistances R_1 and R_2 each 60Ω are connected in series as shown in figure. The Potential difference between A and B is kept 120 volt. Then what will be the reading of voltmeter connected between the point C & D if resistance of voltmeter is 120Ω.



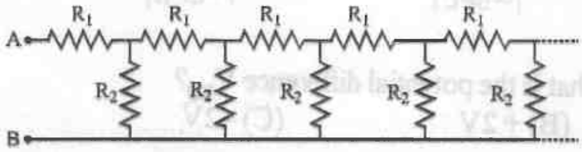
(A) 48 V (B) 24 V
(C) 40V (D) None

Q.18 The resistance of all the wires between any two adjacent dots is R. Then equivalent resistance between A and B as shown in figure is :



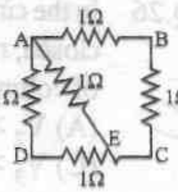
(A) 7/3 R (B) 7/6 R
(C) 14/8 R (D) None of these

Q.19 Consider an infinte ladder network shown in figure. A voltage V is applied between the points A and B. This applied value of voltage is halved after each section.



(A) $R_1/R_2 = 1$ (B) $R_1/R_2 - 1/2$ (C) $R_1/R_2 = 2$ (D) $R_1/R_2 = 3$

Q.20 ABCD is a square where each side is a uniform wire of resistance 1Ω. A point E lies on CD such that if a uniform wire of resistance 1Ω is connected across AE and constant potential difference is applied across A and C then B and E are equipotential.

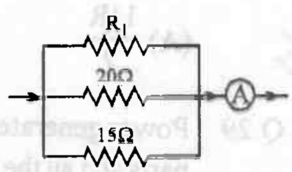


(A) $\frac{CE}{ED} = 1$ (B) $\frac{CE}{ED} = 2$ (C) $\frac{CE}{ED} = \frac{1}{\sqrt{2}}$ (D) $\frac{CE}{ED} = \sqrt{2}$

Q.21 In order to increase the resistance of a given wire of uniform cross section to four times its value, a fraction of its length is stretched uniformly till the full length of the wire becomes $\frac{3}{2}$ times the original length what is the value of this fraction?

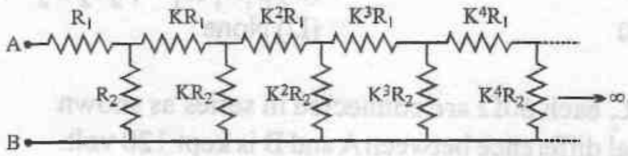
(A) $\frac{1}{4}$ (B) $\frac{1}{8}$ (C) $\frac{1}{16}$ (D) $\frac{1}{6}$

Q.22 In the given circuit the current flowing through the resisitance 20 ohms is 0.3 ampere while the ammetre reads 0.8 ampere. What is the value of R_1?



(A) 30 ohms (B) 40 ohms (C) 50 ohms (D) 60 ohms

Q.23 The circuit diagram shown consists of a large number of element (each element has two resistors R_1 and R_2). The resistance of the resistors in each subsequent element differs by a factor of $K = 1/2$ from the resistance of the resistors in the previous elements. The equivalent resistance between A and B shown in figure is :



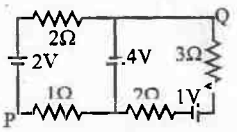
(A) $\frac{R_1 - R_2}{2}$ (B) $\frac{(R_1 - R_2) + \sqrt{6R_1R_2}}{2}$

(C) $\frac{(R_1 - R_2) + \sqrt{R_1^2 + R_2^2 + 6R_1R_2}}{2}$ (D) None of these

Q.24 A brass disc and a carbon disc of same radius are assembled alternatively to make a cylindrical conductor. The resistance of the cylinder is independent of the temperature. The ratio of thickness of the brass disc to that of the carbon disc is [α is temperature coefficient of resistance & Neglect linear expansion]

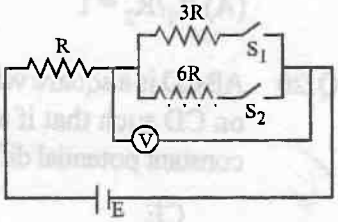
(A) $\left|\frac{\alpha_C\rho_C}{\alpha_B\rho_B}\right|$ (B) $\left|\frac{\alpha_C\rho_B}{\alpha_B\rho_C}\right|$ (C) $\left|\frac{\alpha_B\rho_C}{\alpha_C\rho_B}\right|$ (D) $\left|\frac{\alpha_B\rho_B}{\alpha_C\rho_C}\right|$

Q.25 In the circuit shown, what is the potential difference V_{PQ}?



(A) + 3V (B) + 2V (C) –2V (D) none

Q.26 In the circuit shown in figure reading of voltmeter is V_1 when only S_1 is closed, reading of voltmeter is V_2 when only S_2 is closed. The reading of voltmeter is V_3 when both S_1 and S_2 are closed then

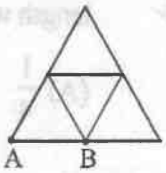


(A) $V_2 > V_1 > V_3$ (B) $V_3 > V_2 > V_1$
(C) $V_3 > V_1 > V_2$ (D) $V_1 > V_2 > V_3$

Q.27 One end of a Nichrome wire of length 2L and cross-sectional area A is attatched to an end of another Nichrome wire of length L and cross-sectional area 2A. If the free end of the longer wire is at an electric potential of 8.0 volts, and the free end of the shorter wire is at an electric potential of 1.0 volt, the potential at the junction of the two wires is equal to

(A) 2.4 V (B) 3.2 V (C) 4.5 V (D) 5.6 V

Q.28 In the diagram resistance between any two junctions is R. Equivalent resistance across terminals A and B is



(A) $\frac{11R}{7}$ (B) $\frac{18R}{11}$ (C) $\frac{7R}{11}$ (D) $\frac{11R}{18}$

Q.29 Power generated across a uniform wire connected across a supply is H. If the wire is cut into n equal parts and all the parts are connected in parallel across the same supply, the total power generated in the wire is

(A) $\frac{H}{n^2}$ (B) n^2H (C) nH (D) $\frac{H}{n}$

Q.30 A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is developed in it. The heat developed is doubled if
(A) both the length and the radius of the wire are halved.
(B) both the length and the radius of the wire are doubled
(C) the radius of the wire is doubled
(D) the length of the wire is doubled

Q.31 When electric bulbs of same power, but different marked voltage are connected in series across the power line, their brightness will be :
(A) proportional to their marked voltage
(B) inversely proportional to their marked voltage
(C) proportional to the square of their marked voltage
(D) inversely proportional to the square of their marked voltage
(E) the same for all of them

Q.32 Two bulbs rated (25 W – 220V) and (100W – 220V) are connected in series to a 440 V line. Which one is likely to fuse?
(A) 25 W bulb (B) 100 W bulb (C) both bulbs (D) none

Q.33 Rate of dissipation of Joule's heat in resistance per unit volume is (symbols have usual meaning)
(A) σE (B) σJ (C) J E (D) None

Q.34 The charge flowing through a resistance R varies with time as $Q = 2t - 8t^2$. The total heat produced in the resistance is (for $0 < t \le \frac{1}{8}$)
(A) $\frac{R}{6}$ joules (B) $\frac{R}{3}$ joules (C) $\frac{R}{2}$ joules (D) R joules

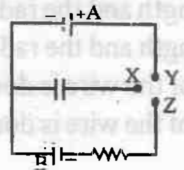
Q.35 A total charge Q flows across a resistor R during a time interval = T in such a way that the current vs. time graph for $0 \to T$ is like the loop of a sin curve in the range $0 \to \pi$. The total heat generated in the resistor is
(A) $Q^2\pi^2R / 8T$ (B) $2Q^2\pi^2R / T$ (C) $2Q^2\pi R / T$ (D) $Q^2\pi^2R / 2T$

Q.36 If the length of the filament of a heater is reduced by 10%, the power of the heater will
(A) increase by about 9% (B) increase by about 11%
(C) increase by about 19% (D) decrease by about 10%

Q.37 A heater A gives out 300 W of heat when connected to a 200 V d.c. supply. A second heater B gives out 600 W when connected to a 200 v d.c. supply. If a series combination of the two heaters is connected to a 200 V d.c. supply the heat output will be
(A) 100 W (B) 450 W (C) 300 W (D) 200 W

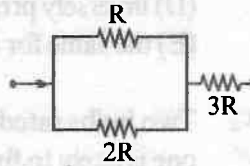
Q.38 Two bulbs one of 200 volts, 60 watts & the other of 200 volts, 100 watts are connected in series to a 200 volt supply. The power consumed will be
(A) 37.5 watt (B) 160 watt (C) 62.5 watt (D) 110 watt

Q.39 In the circuit shown the cells are ideal and of equal emfs, the capacitance of the capacitor is C and the resistance of the resistor is R. X is first joined to Y and then to Z. After a long time, the total heat produced in the resistor will be
(A) equal to the energy finally stored in the capacitor
(B) half of the energy finally stored in the capacitor
(C) twice the energy finally stored in the capacitor
(D) 4 times the energy finally stored in the capacitor



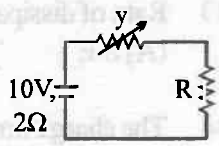
Q.40 Three 60 W light bulbs are mistakenly wired in series and connected to a 120 V power supply Assume the light bulbs are rated for single connection to 120 V With the mistaken connection, the power dissipated by each bulb is:
(A) 6.7 W (B) 13.3 W (C) 20 W (D) 40 W

Q.41 The ratio of powers dissipatted respectively in R and 3R, as shown is:

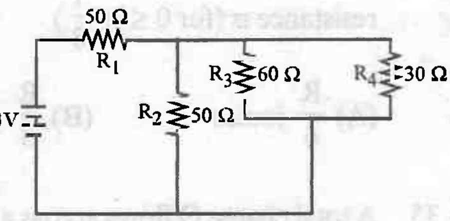


(A) 9 (B) 27/4 (C) 4/9 (D) 4/27

Q.42 In the figure shown the power generated in y is maximum when y = 5Ω. Then R is
(A) 2 Ω (B) 6 Ω
(C) 5 Ω (D) 3 Ω



Q.43 In the circuit shown, the resistances are given in ohms and the battery is assumed ideal with emf equal to 3.0 volts. The resistor that dissipates the most power is
(A) R_1
(B) R_2
(C) R_3
(D) R_4



Q.44 What amount of heat will be generated in a coil of resistance R due to a charge q passing through it if the current in the coil decreases to zero uniformly during a time interval Δt
(A) $\frac{4}{3}\frac{q^2R}{\Delta t}$ (B) $ln\frac{q^2R}{2\Delta t}$ (C) $\frac{2q^2R}{3\Delta t}$ (D) $\ln\frac{(2\Delta t)}{q^2R}$

Q.45 The variation of current (I) and voltage (V) is as shown in figure A. The variation of power P with current *I* is best shown by which of the following graph

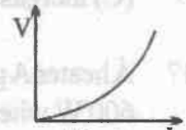
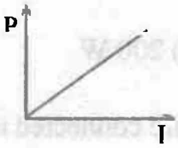
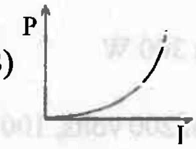
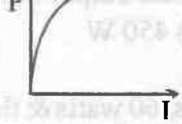
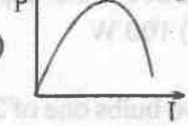


Fig. A

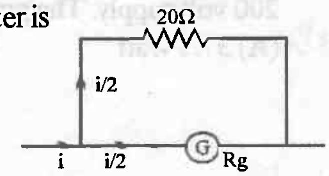
(A) 

(B) 

(C) 

(D) 

Q.46 In a galvanometer, the deflection becomes one half when the galvanometer is shunted by a 20Ω resistor. The galvanometer resistance is
(A) 5Ω (B) 10Ω
(C) 40Ω (D) 20Ω



Q.47 When a galvanometer is shunted with a 4Ω resistance, the deflection is reduced to one-fifth. If the galvanometer is further shunted with 2Ω wire, the further reduction in the deflection will be (the main current remains same)

(A) $\frac{8}{13}$ of the deflection when shunted with 4Ω only

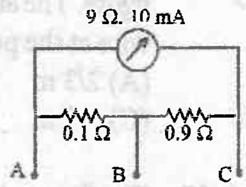
(B) $\frac{5}{13}$ of the deflection when shunted with 4Ω only

(C) $\frac{3}{4}$ of the deflection when shunted with 4Ω only

(D) $\frac{3}{13}$ of the deflection when shunted with 4Ω only

Q.48 A galvanometer has a resistance of 20Ω and reads full-scale when 0.2 V is applied across it. To convert it into a 10 A ammeter, the galvanometer coil should have a
(A) 0.01Ω resistor connected across it (B) 0.02Ω resistor connected across it
(C) 200Ω resistor connected in series with it (D) 2000 Ω resistor connected in series with it

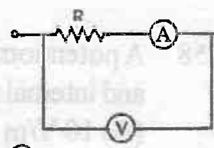
Q.49 A milliammeter of range 10 mA and resistance 9 Ω is joined in a circuit as shown. The metre gives full-scale deflection for current I when A and B are used as its terminals, i.e., current enters at A and leaves at B (C is left isolated). The value of I is



(A) 100 mA (B) 900 mA (C) 1 A (D) 1.1 A

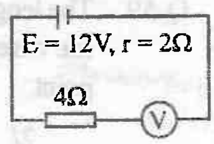
Q.50 A galvanometer coil has a resistance 90 Ω and full scale deflection current 10 mA. A 910Ω resistance is connected in series with the galvanometer to make a voltmeter. If the least count of the voltmeter is 0.1V, the number of divisions on its scale is
(A) 90 (B) 91 (C) 100 (D) none

Q.51 In the circuit shown the resistance of voltmeter is 10,000 ohm and that of ammeter is 20 ohm. The ammeter reading is 0.10 Amp and voltmeter reading is 12 volt. Then R is equal to



(A) 122 Ω (B) 140 Ω (C) 116 Ω (D) 100 Ω

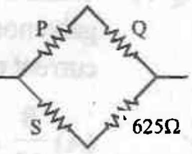
Q.52 By error, a student places moving-coil voltmeter V (nearly ideal) in series with the resistance in a circuit in order to read the current, as shown. The voltmeter reading will be



(A) 0 (B) 4V (C) 6V (D) 12V

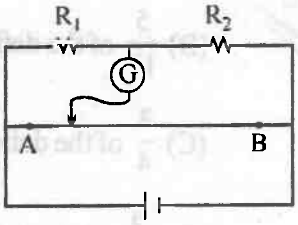
Q.53 In a balanced wheat stone bridge, current in the galvanometer is zero. It remains zero when:
[1] battery emf is increased
[2] all resistances are increased by 10 ohms
[3] all resistances are made five times
[4] the battery and the galvanometer are interchanged
(A) only [1] is correct (B) [1], [2] and [3] are correct
(C) [1], [3] and [4] are correct (D) [1] and [3] are correct

Q.54 A Wheatstone's bridge is balanced with a resistance of 625 Ω in the third arm, where P, Q and S are in the 1st, 2nd and 4th arm respectively. If P and Q are interchanged, the resistance in the third arm has to be increased by 51Ω to secure balance. The unknown resistance in the fourth arm is



(A) 625 Ω (B) 650 Ω (C) 676 Ω (D) 600 Ω

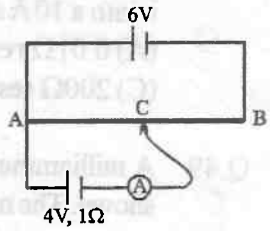
Q.55 In the figure shown for gives values of R_1 and R_2 the balance point for Jockey is at 40 cm from A. When R_2 is shunted by a resistance of 10 Ω, balance shifts to 50 cm. R_1 and R_2 are (AB = 1 m):



(A) $\frac{10}{3}$ Ω, 5 Ω (B) 20 Ω, 30 Ω

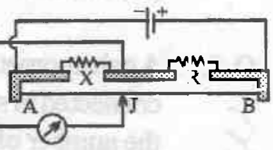
(C) 10 Ω, 15 Ω (D) 5 Ω, $\frac{15}{2}$ Ω

Q.56 A 6 V battery of negligible internal resistance is connected across a uniform wire of length 1 m. The positive terminal of another battery of emf 4V and internal resistance 1 Ω is joined to the point A as shown in figure. The ammeter shows zero deflection when the jockey touches the wire at the point C. The AC is equal to



(A) 2/3 m (B) 1/3 m
(C) 3/5 m (D) 1/2 m

Q.57 The figure shows a metre-bridge circuit, with AB = 100 cm, X = 12Ω and R = 18Ω, and the jockey J in the position of balance. If R is now made 8Ω, through what distance will J have to be moved to obtain balance?



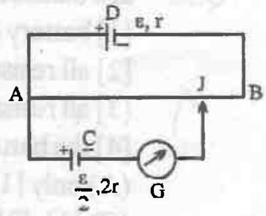
(A) 10 cm (B) 20 cm
(C) 30 cm (D) 40 cm

Q.58 A potentiometer wire has length 10 m and resistance 10Ω. It is connected to a battery of EMF 11 volt and internal resistance 1 Ω, then the potential gradient in the wire is
(A) 10 V/m (B) 1 V/m (C) 0.1 V/m (D) none

Q.59 The length of a potentiometer wire is l. A cell of emf E is balanced at a length $l/3$ from the positive end of the wire. If the length of the wire is increased by $l/2$. At what distance will the same cell give a balance point.

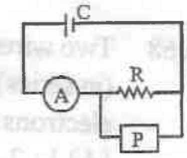
(A) $\frac{2l}{3}$ (B) $\frac{l}{2}$ (C) $\frac{l}{6}$ (D) $\frac{4l}{3}$

Q.60 In the figure, the potentiometer wire AB of length L and resistance 9r is joined to the cell D of emf ε and internal resistance r. The cell C's emf is ε/2 and its internal resistance is 2r. The galvanometer G will show no deflection when the length AJ is



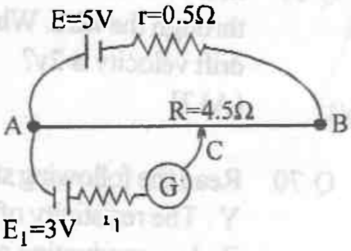
(A) $\frac{4L}{9}$ (B) $\frac{5L}{9}$ (C) $\frac{7L}{18}$ (D) $\frac{11L}{18}$

Q.61 An ammeter A of finite resistance, and a resistor R are joined in series to an ideal cell C. A potentiometer P is joined in parallel to R. The ammeter reading is I_0 and the potentiometer reading is V_0. P is now replaced by a voltmeter of finite resistance. The ammeter reading now is I and the voltmeter reading is V.



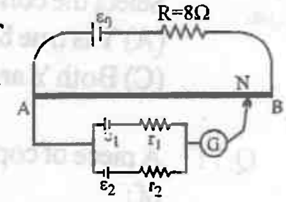
(A) $I > I_0$, $V < V_0$ (B) $I > I_0$, $V = V_0$ (C) $I = I_0$, $V < V_0$ (D) $I < I_0$, $V = V_0$

Q.62 In the given potentiometer circuit length of the wire AB is 3 m and resistance is $R = 4.5\ \Omega$. The length AC for no deflection in galvanometer is



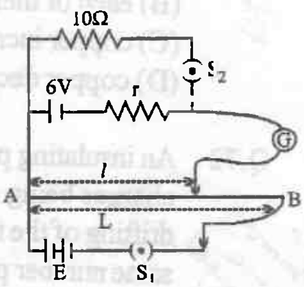
(A) 2 m (B) 1.8 m
(C) dependent on r_1 (D) none of these

Q.63 A battery of emf $E_0 = 12$ V is connected across a 4m long uniform wire having resistance 4Ω/m. The cells of small emfs $\varepsilon_1 = 2$V and $\varepsilon_2 = 4$V having internal resistance 2Ω and 6Ω respectively, are connected as shown in the figure. If galvanometer shows no deflection at the point N, the distance of point N from the point A is equal to



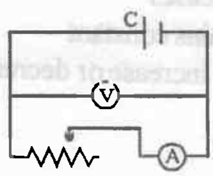
(A) $\frac{1}{6}$ m (B) $\frac{1}{3}$ m (C) 25 cm (D) 50 cm

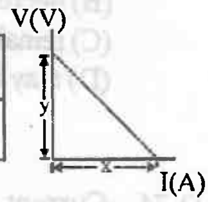
Q.64 In the arrangement shown in figure when the switch S_2 is open, the galvanometer shows no deflection for $l = L/2$. When the switch S_2 is closed, the galvanometer shows no deflection for $l = 5L/12$. The internal resistance (r) of 6 V cell, and the emf E of the other battery are respectively



(A) 3Ω, 8V (B) 2Ω, 12V
(C) 2Ω, 24V (D) 3Ω, 12V

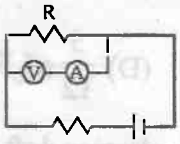
Q.65 The diagram besides shows a circuit used in an experiment to determine the emf and internal resistance of the cell C. A graph was plotted of the potential difference V between the terminals of the cell against the current I, which was varied by adjusting the rheostat. The graph is shown on the right ; x and y are the intercepts of the graph with the axes as shown. What is the internal resistance of the cell ?

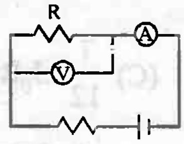


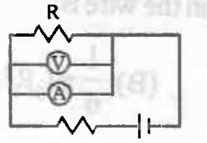


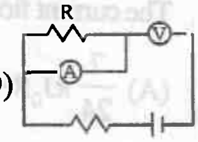
(A) x (B) y
(C) x/y (D) y/x

Q.66 Which of the following wiring diagrams could be used to experimentally determine R using ohm's law? Assume an ideal voltmeter and an ideal ammeter.

(A) 

(B) 

(C) 

(D) 

Q.67 A current of (2.5 ± 0.05) A flows through a wire and develops a potential difference of (10 ± 0.1) volt. Resistance of the wire in ohm, is
(A) 4 ± 0.12 (B) 4 ± 0.04 (C) 4 ± 0.08 (D) 4 ± 0.02

Q.68 Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carriers in the two wires are in the ratio 1 : 4, the drift velocity of electrons in the two wires will be in the ratio:
(A) 1 : 2 (B) 2 : 1 (C) 4 : 1 (D) 1 : 4

Q.69 In a wire of cross-section radius r, free electrons travel with drift velocity v when a current I flows through the wire. What is the current in another wire of half the radius and of the same material when the drift velocity is 2v?
(A) 2I (B) I (C) I/2 (D) I/4

Q.70 Read the following statements carefully :
Y : The resistivity of a semiconductor decreases with increases of temperature.
Z : In a conducting solid, the rate of collision between free electrons and ions increases with increase of temperature.
Select the correct statement from the following :
(A) Y is true but Z is false (B) Y is false but Z is true.
(C) Both Y and Z are true. (D) Y is true and Z is the correct reason for Y.

Q.71 A piece of copper and another of germanium are cooled from room temperature to 80 K. The resistance of:
(A) each of them increases
(B) each of them decreases
(C) copper increases and germanium decreases
(D) copper decreases and germanium increases.

Q.72 An insulating pipe of cross-section area 'A' contains an electrolyte which has two types of ions→ their charges being –e and +2e. A potential difference applied between the ends of the pipe result in the drifting of the two types of ions, having drift speed = v (–ve ion) and v/4 (+ve ion). Both ions have the same number per unit volume = n. The current flowing through the pipe is
(A) nev A/2 (B) nev A/4 (C) 5nev A/2 (D) 3nev A/2

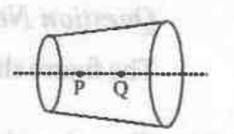
Q.73 As the temperature of a conductor increases, its resistivity and conductivity change. The ratio of resistivity to conductivity
(A) increases
(B) decreases
(C) remains constant
(D) may increase or decrease depending on the actual temperature.

Q.74 Current density in a cylindrical wire of radius R is given as $J = \begin{cases} J_0\left(\frac{x}{R}-1\right) \text{for } 0 < x < \frac{R}{2} \\ J_0\frac{x}{R} \text{for } \frac{R}{2} < x < R \end{cases}$

The current flowing in the wire is:
(A) $\frac{7}{24}\pi J_0 R^2$ (B) $\frac{1}{6}\pi J_0 R^2$ (C) $\frac{7}{12}\pi J_0 R^2$ (D) $\frac{5}{12}\pi J_0 R^2$

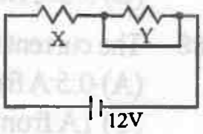
Q.75 A current I flows through a uniform wire of diameter d when the mean electron drift velocity is V. The same current will flow through a wire of diameter d/2 made of the same material if the mean drift velocity of the electron is :
(A) v/4 (B) v/2 (C) 2v (D) 4v

Q.76 A wire has a non-uniform cross-section as shown in figure. A steady current flows through it. The drift speed of electrons at points P and q is v_P and v_Q.



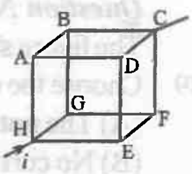
(A) $v_P = v_Q$ (B) $v_P < v_Q$
(C) $v_P > v_Q$ (D) Data insufficient

Q.77 When an ammeter of negligible internal resistance is inserted in series with circuit it reads 1A. When the voltmeter of very large resistance is connected across X it reads 1V. When the point A and B are shorted by a conducting wire, the voltmeter measures 10 V across the battery. The internal resistance of the battery is equal to



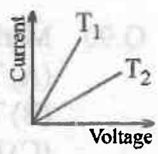
(A) zero
(B) 0.5 Ω
(C) 0.2 Ω
(D) 0.1 Ω

Q.78 In the box shown current i enters at H and leaves at C. If $i_{AB} = \frac{i}{6}$, $i_{DC} = \frac{2i}{3}$, $i_{HA} = \frac{i}{2}$, $i_{GF} = \frac{i}{6}$, $i_{HE} = \frac{i}{6}$, choose the branch in which current is zero



(A) BG (B) FC (C) ED (D) none

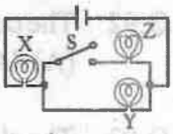
Q.79 The current in a metallic conductor is plotted against voltage at two different temperatures T_1 and T_2. Which is correct



(A) $T_1 > T_2$ (B) $T_1 < T_2$
(C) $T_1 = T_2$ (D) none

Q.80 A uniform copper wire carries a current i amperes and has p carriers per metre^3. The length of the wire is ℓ metres and its cross-section area is s metre^2. If the charge on a carrier is q coulombs, the drift velocity in ms^{-1} is given by
(A) $i/\ell sq$ (B) i/psq (C) psq/i (D) $i/ps\ell q$

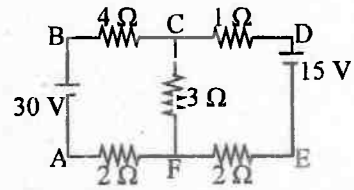
Q.81 If X, Y and Z in figure are identical lamps, which of the following changes to the brightnesses of the lamps occur when switch S is closed?



(A) X stays the same, Y decreases (B) X increases, Y decreases
(C) X increases, Y stays the same (D) X decreases, Y increases

Question No. 82 to 85 (4 questions)

The figure shows a network of five resistances and two batteries



Q.82 The current through the 30V battery is
(A) 3A (B) 1A (C) 2A (D) none

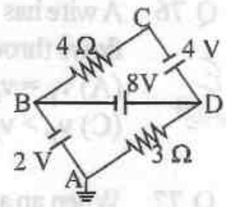
Q.83 The current through the 15V battery is
(A) zero (B) 1A (C) 3A (D) none

Q.84 Which of the batteries is getting charged.
(A) 30V (B) 15V (C) both (D) none

Q.85 The total electrical power consumed by the circuit is
(A) 15W (B) 75W (C) 105W (D) 90W

Question No. 86 to 88 (3 questions)

The figure shows a network of resistances in which the point A is earthed.



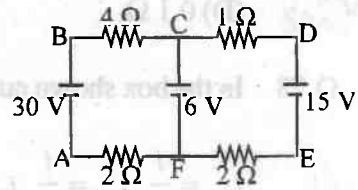
Q.86 The point which has the least potential is
(A) A (B) B (C) C (D) D

Q.87 The current through the 3Ω resistor is
(A) 2A from D to A (B) 2A from A to D
(C) 3.33A from A to D (D) 3.33A from D to A

Q.88 The current through the 4Ω resistor is
(A) 0.5 A from B to C (B) 0.5A from C to B
(C) 1A from C to B (D) 1A from B to C

Question No. 89 to 93 (5 questions)

The figure shows a network of four resistances and three batteries



Q.89 Choose the correct alternative
(A) The potential difference $V_C - V_F = 6V$.
(B) No current flows in the branch CF.
(C) Current flows in the branch from F to C.
(D) Both (A) and (C)

Q.90 Mark the incorrect statement.
(A) The current flowing in the left loop is independent of the right loop.
(B) The current flowing in the right loop is independent of the left loop.
(C) Both 30V and 15V batteries do not produce current in the branch CF
(D) both (A) and (B)

Q.91 Which of the battery is getting charged.
(A) Only 6V (B) both 6V and 15V (C) Only 15V (D) None

Q.92 The current through the branch CF is
(A) 4A (B) 3A (C) 7A (D) 1A

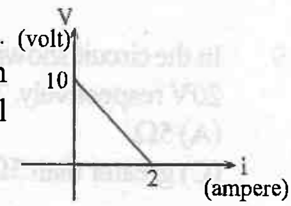
Q.93 The electrical power dissipated as heat is
(A) 207 W (B) 123 W (C) 165 W (D) none

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 A battery is of emf E is being charged from a charger such that positive terminal of the battery is connected to terminal A of charger and negative terminal of the battery is connected to terminal B of charger. The internal resistance of the battery is r.
(A) Potential difference across points A and B must be more than E.
(B) A must be at higher potential than B
(C) In battery, current flows from positive terminal to the negative terminal
(D) No current flows through battery

Q.2 A battery of emf E and internal resistance r is connected across a resistance R. Resistance R can be adjusted to any value greater than or equal to zero. A graph is plotted between the current (i) passing through the resistance and potential difference (V) across it. Select the correct alternative(s).

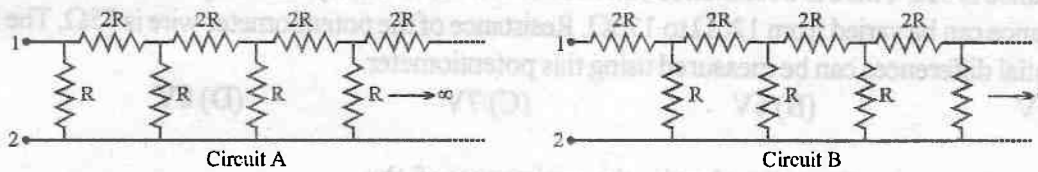


(A) internal resistance of battery is 5Ω
(B) emf of the battery is 20V
(C) maximum current which can be taken from the battery is 4A
(D) V- i graph can never be a straight line as shown in figure.

Q.3 The equivalent resistance of a group of resistances is R. If another resistance is connected in parallel to the group, its new equivalent becomes R_1 & if it is connected in series to the group, its new equivalent becomes R_2 we have :
(A) $R_1 > R$ (B) $R_1 < R$ (C) $R_2 > R$ (D) $R_2 < R$

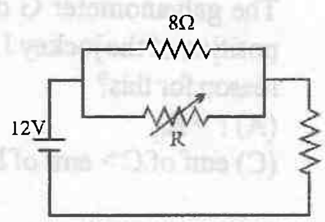
Q.4 Two identical fuses are rated at 10A. If they are joined
(A) in parallel, the combination acts as a fuse of rating 20A
(B) in parallel, the combination acts as a fuse of rating 5A
(C) in series, the combination acts as a fuse of rating 10A.
(D) in series, the combination acts as a fuse of rating 20A.

Q.5 Two circuits (shown below) are called 'Circuit A' and 'Circuit B'. The equivalent resistance of 'Circuit a' is x and that of 'Circuit B' is y between 1 and 2.



(A) $y > x$ (B) $y = (\sqrt{3} + 1)$ R (C) $x\,y = 2R^2$ (D) $x - y = 2R$

Q.6 The value of the resistance R in figure is adjusted such that power dissipated in the 2Ω resistor is maximum. Under this condition



(A) R = 0
(B) R = 8Ω
(C) power dissipated in the 2 Ω resistor is 72 W.
(D) power dissipated in the 2 Ω resistor is 8 W.

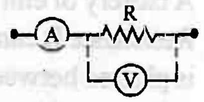
Q.7 A galvanometer may be converted into ammeter or voltmeter. In which of the following cases the resistance of the device will be the largest ? (Asssume maximum range of galvanometer = 1 mA)

(A) an ammeter of range 10 A (B) a voltmeter of range 5 V
(C) an ammeter of range 5 A (D) a voltmeter of range 10 V

Q.8 Mark out the correct options.

(A) An ammeter should have small resistance.
(B) An ammeter should have large resistance.
(C) A voltmeter should have small resistance.
(D) A voltmeter should have large resistance.

Q.9 In the circuit shown the readings of ammeter and voltmeter are 4A and 20V respectively. The meters are non ideal, then R is :



(A) 5Ω (B) less than 5Ω
(C) greater than 5Ω (D) between 4Ω & 5Ω

Q.10 A micrometer has a resistance of 100Ω and a full scale range of 50μA. It can be used as a voltmeter or a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination(s).

(A) 50 V range with 10 kΩ resistance in series. (B) 10 V range with 200 kΩ resistance in series.
(C) 5 mA range with 1 Ω resistance in parallel. (D) 10 mA range with 1 kΩ resistance in parallel.

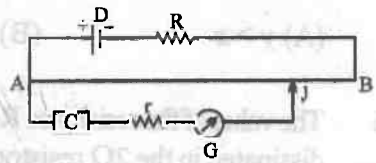
Q.11 In a potentiometer arrangement. E_1 is the cell establishing current in primary circuit. E_2 is the cell to be measured. AB is the potentiometer wire and G is a galvanometer. Which of the following are the essential condition for balance to be obtained.

(A) The emf of E_1 must be greater than the emf of E_2.
(B) Either the positive terminals of both E_1 and E_2 or the negative terminals of both E_1 and E_2 must be joined to one end of potentiometer wire.
(C) The positive terminals of E_1 and E_2 must be joined to one end of potentiometer wire.
(D) The resistance of G must be less than the resistance of AB.

Q.12 In a potentiometer wire experiment the emf of a battery in the primary circuit is 20V and its internal resistance is 5Ω. There is a resistance box in series with the battery and the potentiometer wire, whose resistance can be varied from 120Ω to 170Ω. Resistance of the potentiometer wire is 75Ω. The following potential differences can be measured using this potentiometer.

(A) 5V (B) 6V (C) 7V (D) 8V

Q.13 In the given potentiometer circuit, the resistance of the potentiometer wire AB is R_0. C is a cell of internal resistance r. The galvanometer G does not give zero deflection for any position of the jockey J. Which of the following cannot be a reason for this?

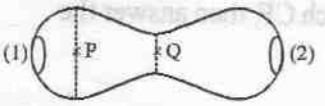


(A) $r > R_0$ (B) $R >> R_0$
(C) emf of C > emf of D (D) The negative terminal of C is connected to A.

Q.14 Which of the following quantities do not change when a resistor connected to a battery is heated due to the current?

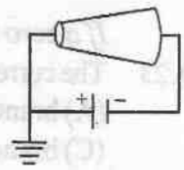
(A) drift speed (B) resistivity (C) resistance (D) number of free electrons

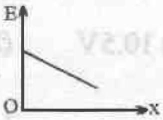
Q.15 A metallic conductor of irregular cross-section is as shown in the figure. A constant potential difference is applied across the ends (1) and (2). Then :

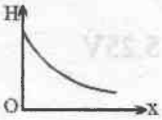


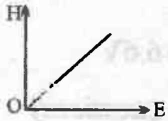
(A) the current at the cross-section P equals the current at the cross-section Q
(B) the electric field intensity at P is less than that at Q.
(C) the rate of heat generated per unit time at Q is greater than that at P
(D) the number of electrons crossing per unit area of cross-section at P is less than that at Q.

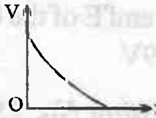
Q.16 A conductor is made of an isotropic material and has shape of a truncated cone. A battery of constant emf is connected across it and its left end is earthed as shown in figure. If at a section distant x from left end, electric field intensity, potential and the rate of generation of heat per unit length are E, V and H respectively, which of the following graphs is/are correct?



(A)


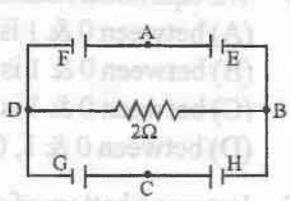
(B)


(C)


(D)


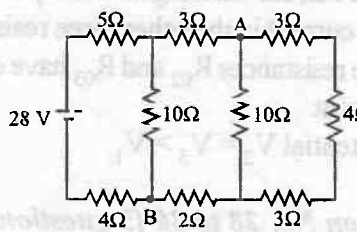
Q.17 A simple circuit contains an ideal battery and a resistance R. If a second resistor is placed in parallel with the first,
(A) the potential across R will decrease
(B) the current through R will decreased
(C) the current delivered by the battery will increase
(D) the power dissipated by R will increased.

Q.18 In the circuit shown E, F, G and H are cells of e.m.f. 2V, 1V, 3V and 1V respectively and their internal resistances are 2Ω, 1Ω, 3Ω and 1Ω respectively.



(A) $V_D - V_B = -2/13$ V
(B) $V_D - V_B = 2/13$ V
(C) $V_G = 21/13$ V = potential difference across G.
(D) $V_H = 19/13$ V = potential difference across H.

Q.19 Consider the circuit shown in the figure

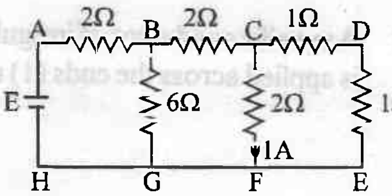


(A) the current in the 5 Ω resistor is 2 A
(B) the current in the 5 Ω resistor is 1 A
(C) the potential difference $V_A - V_B$ is 10 V
(D) the potential difference $V_A - V_B$ is 5 V

Q.20 A current passes through a wire of nonuniform cross section. Which of the following quantities are independent of the cross-section?
(A) the charge crossing in a given time interval.
(B) drift speed
(C) current density
(D) free-electron density.

Question No. 21 to 24 (4 questions)

The figure shows a network of resistors and a battery. If 1A current flows through the branch CF, then answer the following questions



Q.21 The current through
(A) branch DE is 1A (B) branch BC is 2A
(C) branch BG is 4A (D) branch HG is 6A

Q.22 The emf E of the battery is
(A) 24 V (B) 12 V (C) 18V (D) 6V

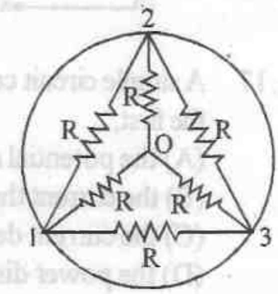
If a zero resistance wire is connected in parallel to branch CF

Q.23 The current through
(A) branch DE is zero (B) branch BC is zero
(C) branch BG is 0.5A (D) branch AB is 1.5A

Q.24 The emf E of the battery is
(A) 9V (B) 6.6V (C) 5.25V (D) 10.5V (E) 12V

Question No. 25 to 27 (3 questions)

Inside a super conducting ring six identical resistors each of resistance R are connected as shown in figure.



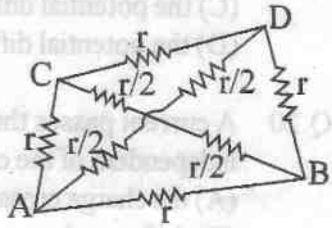
Q.25 The equivalent resistance(s)
(A) between 1 & 3 is zero.
(B) between 1 & 3 is R/2
(C) between 1 & 2, 2 & 3, 3 & 1 are all equal.
(D) between 1 & 3 is two times that between 1 & 2.

Q.26 The equivalent resistance(s)
(A) between 0 & 1 is R.
(B) between 0 & 1 is R/3
(C) between 0 & 1 is zero.
(D) between 0 & 1, 0 & 2 and 0 & 3 are all equal.

Q.27 Imagine a battery of emf E between the point 0 and 1, with its positive terminal connected with O.
(A) The current entering at O is equally divided into three resistances.
(B) the current in the other three resistances R_{12}, R_{13}, R_{23} is zero.
(C) The resistances R_{02} and R_{03} have equal magnitudes of current while the resistance R_{01} have different current.
(D) Potential $V_2 = V_3 > V_1$.

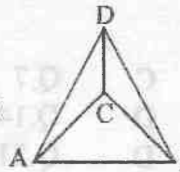
Question No. 28 to 30 (3 questions)

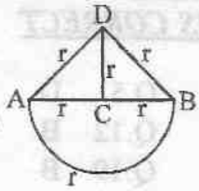
The figure shows a tetrahedron, each side of which has a resistance r

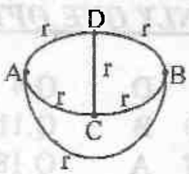


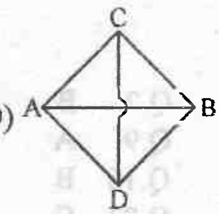
Q.28 Choose the correct statement(s) related to the resistance between any two points.
(A) $R_{AB} = R_{BD} = R_{BC} = R_{CD} = R_{CA} = R_{AD}$
(B) $R_{AB} = R_{AC} = R_{AD} = R_{BD} = R_{BC} \neq R_{CD}$
(C) R_{CD} is the least
(D) $R_{AB} = R_{AC} = R_{BC}$ and $R_{CD} = R_{AD} = R_{BD}$

Q.29 Choose the correct diagram(s), which show two-dimensional equivalent of the tetrahedron.

(A) 

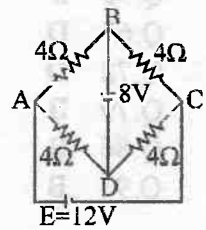
(B) 

(C) 

(D) 

Q.30 If a battery is connected between any two points of the tetrahedron, then identify the correct statement(s).
(A) The potentials of the other two points are always equal.
(B) There always exists a branch through which no current flows.
(C) The current coming out of the battery in each case is same.
(D) None of these

Question No. 31 to 33 (3 questions)
The given figure shows a network of resistances and a battery.



Q.31 Identify the correct statement(s)
(A) The circuit satisfies the condition of a balanced Wheatstone bridge.
(B) $V_B - V_D = 0$
(C) $V_B - V_D = 8$
(D) no current flows in the branch BD

Q.32 Which of the two batteries is getting charged?
(A) 8V battery (B) 12 V battery (C) none (D) can't be said

Q.33 Choose the correct statement(s).
(A) The current coming out of the 8V battery is 2A
(B) The current coming out of the 12V battery is 3A
(C) The current flowing in all the 4Ω branches is same.
(D) The current flowing in the diagonally opposite branches is same

ANSWER KEY

ONLY ONE OPTION IS CORRECT.

Q.1	C	Q.2	B	Q.3	D	Q.4	A	Q.5	D	Q.6	C	Q.7	D
Q.8	C	Q.9	A	Q.10	B	Q.11	C	Q.12	B	Q.13	D	Q.14	C
Q.15	C	Q.16	B	Q.17	A	Q.18	B	Q.19	B	Q.20	D	Q.21	B
Q.22	D	Q.23	C	Q.24	A	Q.25	B	Q.26	A	Q.27	A	Q.28	D
Q.29	B	Q.30	B	Q.31	C	Q.32	A	Q.33	C	Q.34	A	Q.35	A
Q.36	B	Q.37	D	Q.38	A	Q.39	D	Q.40	A	Q.41	D	Q.42	D
Q.43	A	Q.44	A	Q.45	B	Q.46	D	Q.47	A	Q.48	B	Q.49	C
Q.50	C	Q.51	D	Q.52	D	Q.53	C	Q.54	B	Q.55	A	Q.56	A
Q.57	B	Q.58	B	Q.59	B	Q.60	B	Q.61	A	Q.62	D	Q.63	C
Q.64	B	Q.65	D	Q.66	B	Q.67	A	Q.68	C	Q.69	C	Q.70	C
Q.71	D	Q.72	D	Q.73	A	Q.74	D	Q.75	D	Q.76	C	Q.77	C
Q.78	B	Q.79	B	Q.80	B	Q.81	B	Q.82	A	Q.83	B	Q.84	D
Q.85	C	Q.86	B	Q.87	A	Q.88	C	Q.89	A	Q.90	C	Q.91	A
Q.92	C	Q.93	B										

ONE OR MORE THAN ONE OPTION MAY BE CORRECT.

Q.1	A,B,C	Q.2	A	Q.3	B,C	Q.4	A,C
Q.5	A,B,C	Q.6	A,C	Q.7	D	Q.8	A,D
Q.9	C	Q.10	B,C	Q.11	A,B	Q.12	A,B,C
Q.13	A	Q.14	D	Q.15	A,B,C,D	Q.16	B,C
Q.17	C	Q.18	A,C,D	Q.19	A	Q.20	A,D
Q.21	A,B	Q.22	B	Q.23	A	Q.24	E
Q.25	A,C,D	Q.26	B,D	Q.27	A,B	Q.28	A,D
Q.29	A,B,C,D	Q.30	A,B,C	Q.31	C	Q.32	C
Q.33	A,B,D						

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

CURRENT ELECTRICITY

CONTENTS

CURRENT ELECTRICITY

1. ELECTRIC CURRENT :

Electric charges in motion constitute an electric current. Any medium having practically free electric charges, free to migrate is a conductor of electricity. The electric charge flows from higher potential energy state to lower potential energy state. Positive charge flows from higher to lower potential and negative charge flows from lower to higher. Metals such as gold, silver, copper, aluminium etc. are good conductors.

2. ELECTRIC CURRENT IN A CONDUCTOR :

In absence of potential difference across a conductor no net current flows through a corss section. When a potential difference is applied across a conductor the charge carriers (electrons in case of metallic conductors) flow in a definite direction which constitutes a net current in it. These electrons are not accelerated by electric field in the conductor produced by potential difference across the conductor. They move with a constant drift velocity. The direction of current is along the flow of positive charge (or opposite to flow of negative charge). $i = nv_deA$, where V_d = drift velocity.

3. CHARGE AND CURRENT :

The strength of the current i is the rate at which the electric charges are flowing. If a charge Q coulomb passes through a given cross section of the conductor in t second the current I through the conductor is given by $I = \frac{Q}{t} = \frac{\text{Coulomb}}{\text{second}} = \frac{Q}{t}$ ampere.

Ampere is the unit of current. If i is not constant then $i = \frac{dq}{dt}$, where dq is net charge transported at a section in time dt.

In a current carrying conductor we can define a vector which gives the direction as current per unit normal, cross sectional area.

$$\text{Thus } \vec{J} = \frac{I}{S}\hat{n} \text{ or } I = \vec{J} \cdot \vec{S}$$

Where $\hat{n}$ is the unit vector in the direction of the flow of current.

For random J or S, we use $I = \int \vec{J} \cdot \vec{ds}$

4. RELATION IN J, E AND v_D:

In conductors drift vol. of electrons is proportional to the electric field in side the conductor as – $v_d = \mu E$

where μ is the mobility of electrons

current density is given as $J = \frac{I}{A} = ne\,v_d$

$= ne(\mu E) \quad = \sigma E$

where $\sigma = ne\mu$ is called conductivity of material and we can also write $\rho = \frac{1}{\sigma}$ → resistivity of material. Thus $E = \rho J$. It is called as differential form of Ohm's Law.

5. SOURCES OF POTENTIAL DIFFERENCE & ELECTROMOTIVE FORCE :

Dry cells, secondary cells, generator and thermo couple are the devices used for producing potential difference in an electric circuit. The potential difference between the two terminals of a source when no energy is drawn from it is called the "**Electromotive force**" or "**EMF**" of the source. The unit of potential difference is volt.

1 volt = 1 Amphere × 1 Ohm.

6. ELECTRICAL RESISTANCE :

The property of a substance which opposes the flow of electric current through it is termed as electrical resistance. Electrical resistance depends on the size, geometery, temperature and internal structure of the conductor.

7. LAW OF RESISTANCE :

The resistance R offered by a conductor depends on the following factors :

$R \propto L$ (length of the conductor) ; $R \propto \frac{1}{A}$ (cross section area of the conductor)

at a given temperature $R = \rho\frac{l}{A}$.

Where ρ is the resistivity of the material of the conductor at the given temperature. It is also known as **specific resistance** of the material.

8. DEPENDENCE OF RESISTANCE ON TEMPERATURE :

The resistance of most conductors and all pure metals increases with temperature, but there are a few in which resistance decreases with temperature. If R_o & R be the resistance of a conductor at 0° C and θ° C, then it is found that $R = R_o(1 + \alpha\theta)$.

Here we assume that the dimensions of resistance does not change with temperature if expansion coefficient of material is considerable. Then instead of resistance we use same property for resistivity as $\rho = \rho_0(1 + \alpha\theta)$

The materials for which resistance decreases with temperature, the temperature coefficient of resistance is negative.

Where α is called the temperature co-efficient of resistance. The unit of α is K^{-1} of $°C^{-1}$ reciprocal of resistivity is called conductivity and reciprocal of resistance is called conductance (G). S.I. unit of G is ohm.

9. OHM'S LAW :

Ohm's law is the most fundamental of all the laws in electricity. It says that the current through the cross section or the conductor is proportional to the applied potential difference under the given physical condition. V = RI. Ohm's law is applicable to only metalic conductors.

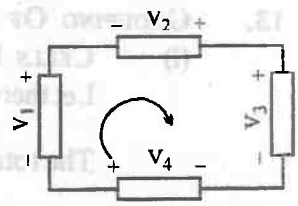
10. KRICHHOFF'S LAW'S :

I - Law (Junction law or Nodal Analysis) : This law is based on law of conservation of charge. It states that " The algebric sum of the currents meeting at a point is zero " or total currents entering a junction equals total current leaving the junction.

$\Sigma I_{in} = \Sigma I_{out}$. It is also known as KCL (Kirchhoff's current law).

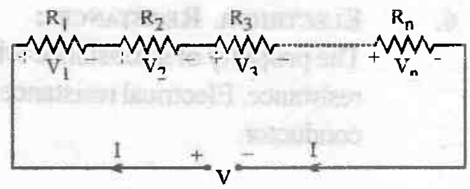
II - Law (Loop analysis) : The algebric sum of all the voltages in closed circuit is zero.

$\Sigma IR + \Sigma EMF = 0$ in a closed loop. The closed loop can be traversed in any direction. While traversing a loop if higher potential point is entered, put a +ve sign in expression or if lower potential point is entered put a negative sign.



$-V_1 - V_2 + V_3 - V_4 = 0$. Boxes may contain resistor or battery or any other element (linear or non-linear). It is also known as **KVL (Kirchhoff's voltage law)**.

11. Combination Of Resistances :



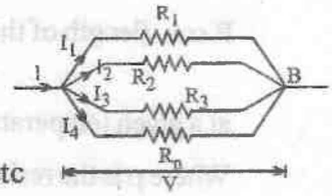
A number of resistances can be connected and all the complecated combinations can be reduced to two different types, namely series and parallel .

(i) Resistance In Series :

When the resistances are connected end toend then they are said to be in series . The current through each resistor is same . The effective resistance appearing across the battery .

$R = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots + R_n$ and

$V = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots + V_n$.



The voltage across a resistor is proportional to the resistance

$$V_1 = \frac{R_1}{R_1+R_2+\ldots\ldots+R_n} V ; V_2 = \frac{R_2}{R_1+R_2+\ldots\ldots+R_n} V \text{ ; etc}$$

(ii) Resistance In Parallel :

A parallel circuit of resistors is one in which the same voltage is applied across all the components in a parallel grouping of resistors $R_1, R_2, R_3, \ldots\ldots, R_n$.

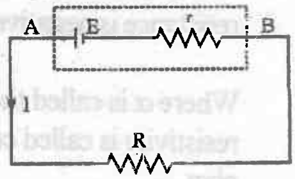
Conclusions :

(a) Potential difference across each resistor is same .

(b) $I = I_1 + I_2 + I_3 + \ldots\ldots\ldots I_n$

(c) Effective resistance (R) then $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots + \frac{1}{R_n}$.

(d) Current in different resistors is inversally proportional to the resistance .



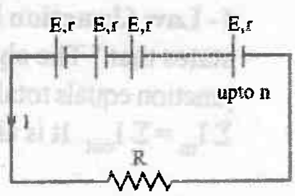
$$I_1 : I_2 \ldots\ldots\ldots I_n = \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3} : \ldots\ldots\ldots : \frac{1}{R_n}$$

$$I_1 = \frac{G_1}{G_1+G_2+\ldots\ldots+G_n} I, \; I_2 = \frac{G_2}{G_1+G_2+\ldots\ldots+G_n} I, \text{ etc.}$$

where $G = \frac{1}{R}$ = Conductance of a resistor .

12. EMF Of A Cell & Its Internal Resistance :

If a cell of emf E and internal resistance r be connected with a resistance R the total resistance of the circuit is (R + r) .



$I = \frac{E}{R+r}$; $V_{AB} = \frac{E}{R+r}$ where

E = Terminal voltage of the battery . If $r \to 0$, cell is Ideal & $V \to E$.

13. Grouping Of Cells :

(i) Cells In Series :

Let there be n cells each of emf E , arranged in series. Let r be the internal resistance of each cell.

The total emf = nE . Current in the circuit $I = \frac{nE}{R+nr}$

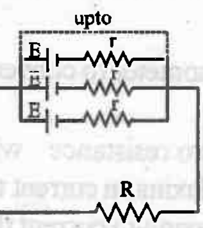
If $nr << R$ then $I = \frac{nE}{R} \longrightarrow$ Series combination should be used .

If $nr >> R$ then $I = \frac{E}{r} \longrightarrow$ Series combination should not be used .

(ii) **CELLS IN PARALLEL :**

If m cells each of emf E & internal resistance r be connected in parallel and if this combination be connected to an external resistance then the emf of the circuit = E.

Internal resistance of the circuit = $\frac{r}{m}$.



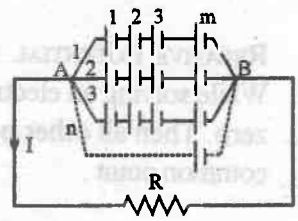
$$I = \frac{E}{R+\frac{r}{m}} = \frac{mE}{mR+r}.$$

If $mR << r$; $I = \frac{mE}{r}$ $\longrightarrow$ Parallel combination should be used.

If $mR >> r$; $I = \frac{E}{R}$ $\longrightarrow$ Parallel combination should not be used.

(iii) **CELLS IN MULTIPLE ARC :**

mn = number of identical cells.
n = number of rows
m = number of cells in each rows.
The combination of cells is equivalent to single cell of :



(a) emf = mE & **(b)** internal resistance = $\frac{mr}{n}$

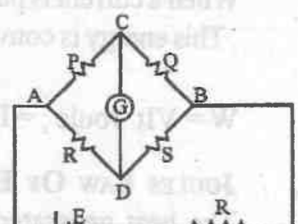
Current $I = \frac{mE}{R+\frac{mr}{n}}$ For maximum current $nR = mr$ or

$R = \frac{mr}{n}$ = internal resistance of battery.

$$I_{max} = \frac{nE}{2r} = \frac{mE}{2R}.$$

WHEAT STONE NETWORK :

When current through the galvanometer is zero (null point or balance point) $\frac{P}{Q} = \frac{R}{S}$. When $PS > QR$; $V_C < V_D$ & $PS < QR$; $V_C > V_D$ or

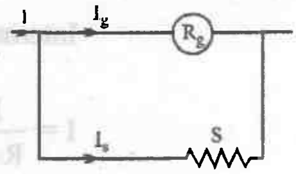


$PS = QR \Rightarrow$ products of opposite arms are equal. Potential difference between C & D at null point is zero. The null point is not affected by resistance of G & E. It is not affected even if the positions of G & E are inter changed. $I_{CD} \propto (QR - PS)$.

14. **POTENTIOMETER :**

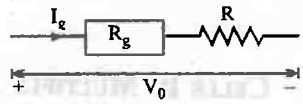
A potentiometer is a linear conductor of uniform cross-section with a steady current set up in it. This maintains a uniform potential gradient along the length of the wire. Any potential difference which is less then the potential difference maintained across the potentiometer wire can be measured using this. The potentiometer equation is $\frac{E_1}{E_2} = \frac{l_1}{l_2}$.

15. **AMMETER :**
It is a modified form of suspended coil galvanometer it is used to measure current . A shunt (small resistance) is connected in parallel with galvanometer to convert into ammeter . $S = \frac{I_g R_g}{I - I_g}$; An ideal ammeter has zero resistance . where
I_g = Maximum current that can flow through the galvanometer .
I = Maximum current that can be measured using the given ammeter .



16. **VOLTMETER :**
A high resistance is put in series with galvanometer . It is used to measure potential difference .

$I_g = \frac{V_0}{R_g + R}$.



$R \to \infty$, Ideal voltmeter .

17. **RELATIVE POTENTIAL :**
While solving an electric circuit it is convinient to chose a reference point and assigning its voltage as zero. Then all other potential are measured with respect to this point . This point is also called the common point .

18. **ELECTRICAL POWER :**
The energy liberated per second in a device is called its power . The electrical power P delivered by an electrical device is given by P = VI , where V = potential difference across device & I = current. If the current enters the higher potential point of the device then power is consumed by it (i.e. acts as load) . If the current enters the lower potential point then the device supplies power (i.e. acts as source) .

Power consumed by a resistor $P = I^2R = VI = \frac{V^2}{R}$.

19. **HEATING EFFECT OF ELECTRIC CURRENT :**
When a current is passed through a resistor energy is wested in over coming the resistances of the wire . This energy is converted into heat .

$W = VIt$ Joule ; $= I^2Rt$ Joule ; $= \frac{V^2}{R}t$ Joule .

20. **JOULES LAW OF ELECTRICAL HEATING :**
The heat generated (in joules) when a current of I ampere flows through a resistance of R ohm for T second is given by :

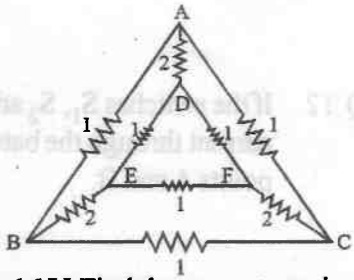
$H = I^2RT$ Joules ; $= \frac{I^2RT}{4.2}$ Calories .

If current is variable passing through the conductor then we use for heat produced in resistance in time 0 to t is: $H = \int_0^t I^2R\,dt$

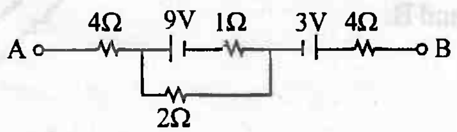
21. **UNIT OF ELECTRICAL ENERGY CONSUMPTION :**
1 unit of electrical energy = Kilowatt hour = 1 KWh = 3.6×10^6 Joules.

EXERCISE # I

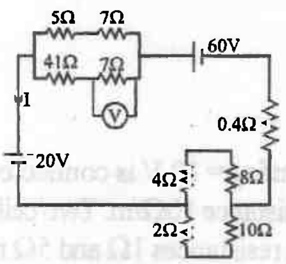
Q.1 A network of nine conductors connects six points A, B, C, D, E and F as shown in figure. The figure denotes resistances in ohms. Find the equivalent resistance between A and D.



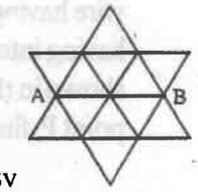
Q.2 In the circuit shown in figure potential difference between point A and B is 16 V. Find the current passing through 2Ω resistance.



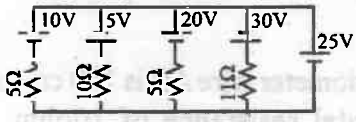
Q.3 Find the current I & voltage V in the circuit shown.



Q.4 Find the equivalent resistance of the circuit between points A and B shown in figure is: (each branch is of resistance = 1Ω)

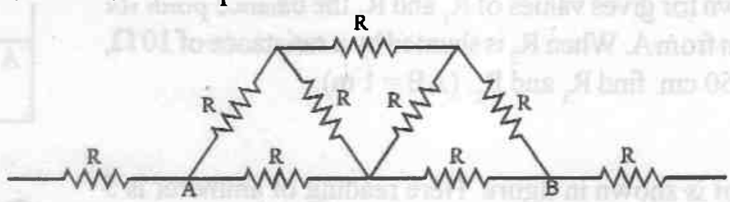


Q.5 Find the current through 25V cell & power supplied by 20V cell in the figure shown.

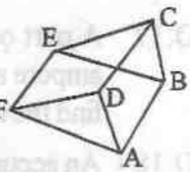


Q.6 If a cell of constant E.M.F. produces the same amount of the heat during the same time in two independent resistors R_1 and R_2, when they are separately connected across the terminals of the cell, one after the another, find the internal resistance of the cell.

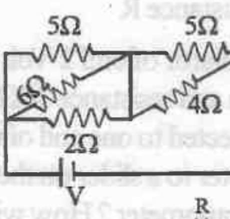
Q.7 Find the effective resistance of the network (see figure) between the points A and B. Where R is the resistance of each part.



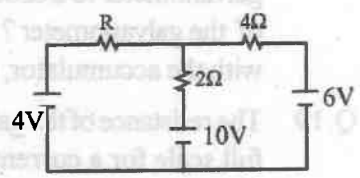
Q.8 In the circuit shown in figure, all wires have equal resistance r. Find the equivalent resistance between A and B.



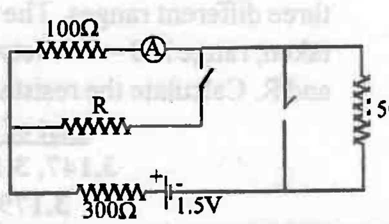
Q.9 Find the resistor in which maximum heat will be produced.



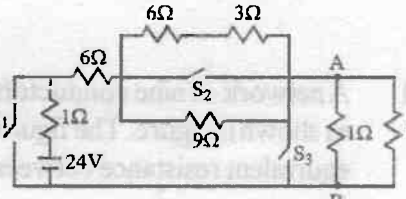
Q.10 For what value of R in circuit, current through 4Ω resistance is zero.



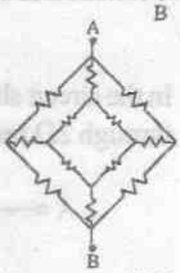
Q.11 In the circuit shown in figure the reading of ammeter is the same with both switches open as with both closed. Then find the resistance R. (ammeter is ideal)



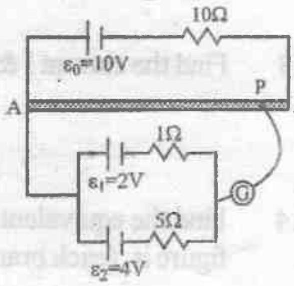
Q.12 If the switches S_1, S_2 and S_3 in the figure are arranged such that current through the battery is minimum, find the voltage across points A and B.



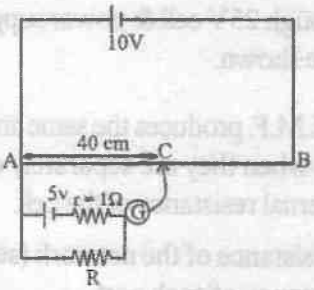
Q.13 The figure shows a network of resistor each heaving value 12Ω. Find the equivalent resistance between points A and B.



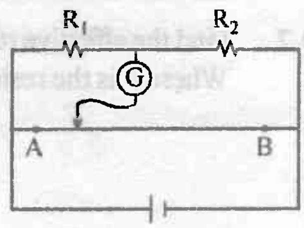
Q.14 A battery of emf $\varepsilon_0 = 10$ V is connected across a 1 m long uniform wire having resistance 10Ω/m. Two cells of emf $\varepsilon_1 = 2$V and $\varepsilon_2 = 4$V having internal resistances 1Ω and 5Ω respectively are connected as shown in the figure. If a galvanometer shows no deflection at the point P, find the distance of point P from the point a.



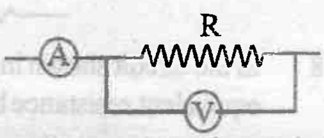
Q.15 A potentiometer wire AB is 100 cm long and has a total resistance of 10ohm. If the galvanometer shows zero deflection at the position C, then find the value of unknown resistance R.



Q.16 In the figure shown for gives values of R_1 and R_2 the balance point for Jockey is at 40 cm from A. When R_1 is shunted by a resistance of 10 Ω, balance shifts to 50 cm. find R_1 and R_2. (AB = 1 m):

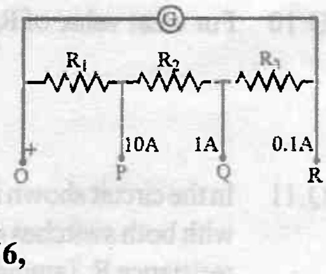


Q.17 A part of a circuit is shown in figure. Here reading of ammeter is 5 ampere and voltmeter is 96V & voltmeter resistance is 480 ohm. Then find the resistance R



Q.18 An accumulator of emf 2 Volt and negligible internal resistance is connected across a uniform wire of length 10m and resistance 30Ω. The appropriate terminals of a cell of emf 1.5 Volt and internal resistance 1Ω is connected to one end of the wire, and the other terminal of the cell is connected through a sensitive galvanometer to a slider on the wire. What length of the wire will be required to produce zero deflection of the galvanometer ? How will the balancing change (a) when a coil of resistance 5Ω is placed in series with the accumulator, (b) the cell of 1.5 volt is shunted with 5Ω resistor ?

Q.19 The resistance of the galvanometer G in the circuit is 25Ω. The meter deflects full scale for a current of 10 mA. The meter behaves as an ammeter of three different ranges. The range is 0–10 A, if the terminals O and P are taken; range is 0 – 1 A between O and Q ; range is 0 – 0.1 A between O and R. Calculate the resistance R_1, R_2 and R_3.



List of recommended questions from I.E. Irodov.

3.147, 3.149, 3.150, 3.154, 3.155, 3.169, 3.175, 3.176, 3.179, 3.186, 3.189, 3.190, 3.194, 3.196, 3.207

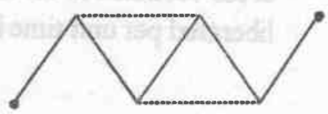
EXERCISE # II

Q.1 A triangle is constructed using the wires AB , BC & CA of same material and of resistance α, 2α & 3α respectively. Another wire of resistance $\alpha/3$ from A can make a sliding contact with wire BC. Find the maximum resistance of the network between points A and the point of sliding wire with BC.

Q.2(a) The current density across a cylindrical conductor of radius R varies according to the equation $J = J_0\left(1-\frac{r}{R}\right)$, where r is the distance from the axis. Thus the current density is a maximum J_o at the axis r = 0 and decreases linearly to zero at the surface r = R. Calculate the current in terms of J_o and the conductor's cross sectional area is $A = \pi R^2$.

(b) Suppose that instead the current density is a maximum J_o at the surface and decreases linearly to zero at the axis so that $J = J_0\frac{r}{R}$. Calculate the current.

Q.3 What will be the change in the resistance of a circuit consisting of five identical conductors if two similar conductors are added as shown by the dashed line in figure.



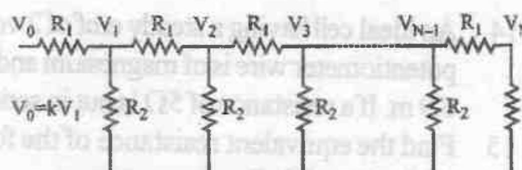
Q.4 The current I through a rod of a certain metallic oxide is given by $I = 0.2\ V^{5/2}$, where V is the potential difference across it. The rod is connected in series with a resistance to a 6V battery of negligible internal resistance. What value should the series resistance have so that :

(i) the current in the circuit is 0.44

(ii) the power dissipated in the rod is twice that dissipated in the resistance.

Q.5 A piece of resistive wire is made up into two squares with a common side of length 10 cm. A currant enters the rectangular system at one of the corners and leaves at the diagonally opposite corners. Show that the current in the common side is 1/5th of the entering current. What length of wire connected between input and output terminals would have an equivalent effect.

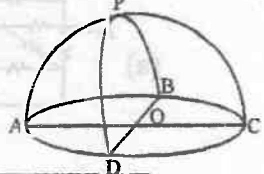
Q.6 A network of resistance is constructed with R_1 & R_2 as shown in the figure. The potential at the points 1, 2, 3,.., N are V_1, V_2, V_3, .., V_n respectively each having a potential k time smaller than previous one. Find:



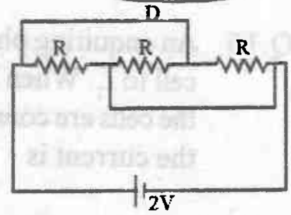
(i) $\frac{R_1}{R_2}$ and $\frac{R_2}{R_3}$ in terms of k

(ii) current that passes through the resistance R_2 nearest to the V_0 in terms V_0, k & R_3.

Q.7 A hemisphere network of radius a is made by using a conducting wire of resistance per unit length r. Find the equivalent resistance across OP.

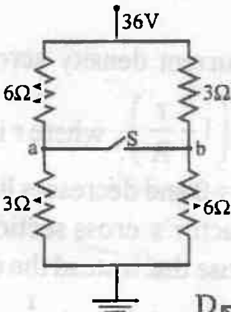


Q.8 Three equal resistance each of R ohm are connected as shown in figure. A battery of 2 volts of internal resistance 0.1 ohm is connected across the circuit. Calculate R for which the heat generated in the circuit is maximum.

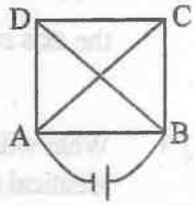


Q.9 A person decides to use his bath tub water to generate electric power to run a 40 watt bulb. The bath tube is located at a height of 10 m from the ground & it holds 200 litres of water. If we install a water driven wheel generator on the ground, at what rate should the water drain from the bath tube to light bulb? How long can we keep the bulb on, if the bath tub was full initially. The efficiency of generator is 90%.($g = 10 m/s^{-2}$)

Q.10 In the circuit shown in figure, calculate the following :
(i) Potential difference between points a and b when switch S is open.
(ii) Current through S in the circuit when S is closed.

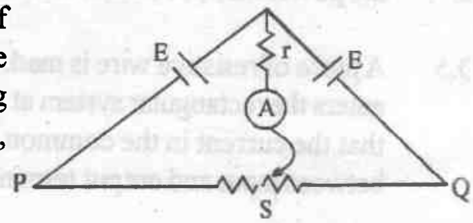


Q.11 The circuit shown in figure is made of a homogeneous wire of uniform cross-section. ABCD is a square. Find the ratio of the amounts of heat liberated per unit time in wire A-B and C-D.



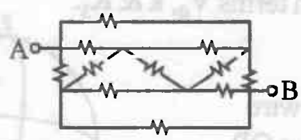
Q.12 A rod of length L and cross-section area A lies along the x-axis between x = 0 and x = L. The material obeys Ohm's law and its resistivity varies along the rod according to $\rho(x) = \rho_0 e^{-x/L}$. The end of the rod at x = 0 is at a potential V_0 and it is zero at x = L.
(a) Find the total resistance of the rod and the current in the wire.
(b) Find the electric potential in the rod as a function of x.

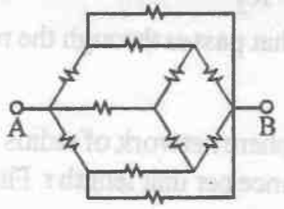
Q.13 In the figure. PQ is a wire of uniform cross-section and of resistance R_0. A is an ideal ammeter and the cells are of negligible resistance. The jockey J can freely slide over the wire PQ making contact on it at S. If the length of the wire PS is f = 1/nth of PQ, find the reading on the ammeter. Find the value of 'f' for maximum and minimum reading on the ammeter.



Q.14 An ideal cell having a steady emf of 2 volt is connected across the potentiometer wire of length 10 m. The potentiometer wire is of magnesium and having resistance of 11.5 Ω/m. An another cell gives a null point at 6.9 m. If a resistance of 5Ω is put in series with potentiometer wire, find the new position of the null point.

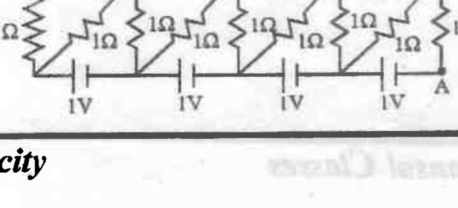
Q.15 Find the equivalent resistance of the following group of resistances between A and B. Each resistance of the circuit is R

(a) 

(b) 

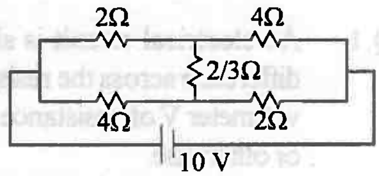
Q.16 An enquiring physics student connects a cell to a circuit and measures the current drawn from the cell to I_1. When he joins a second identical cell is series with the first, the current becomes I_2. When the cells are connected are in parallel, the current through the circuit is I_3. Show that relation between the current is $3 I_3 I_2 = 2 I_1 (I_2 + I_3)$

Q.17 Find the potential difference $V_A - V_B$ for the circuit shown in the figure.



Q.18 A resistance R of thermal coefficient of resistivity = α is connected in parallel with a resistance = 3R, having thermal coefficient of resistivity = 2α. Find the value of α_{eff}.

Q.19 Find the current through $\frac{2}{3}\Omega$ resistance in the figure shown.

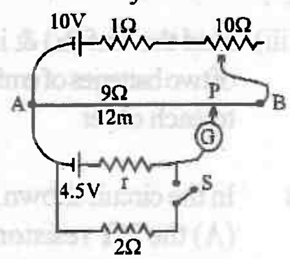


Q.20 A galvanometer having 50 divisions provided with a variable shunt s is used to measure the current when connected in series with a resistance of 90 Ω and a battery of internal resistance 10 Ω. It is observed that when the shunt resistance are 10Ω, 50Ω, respectively the deflection are respectively 9 & 30 divisions. What is the resistance of the galvanometer? Further if the full scale deflection of the galvanometer movement is 300 mA, find the emf of the cell.

Q.21 In the primary circuit of potentiometer the rheostat can be varied from 0 to 10Ω. Initially it is at minimum resistance (zero).

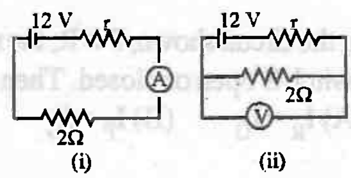
(a) Find the length AP of the wire such that the galvanometer shows zero deflection.

(b) Now the rheostat is put at maximum resistance (10Ω) and the switch S is closed. New balancing length is found to be 8m. Find the internal resistance r of the 4.5V cell.



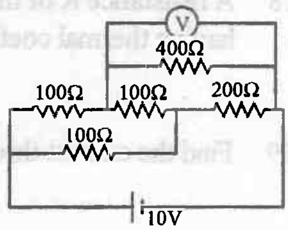
Q.22 A galvanometer (coil resistance 99 Ω) is converted into a ammeter using a shunt of 1Ω and connected as shown in the figure (i). The ammeter reads 3A. The same galvanometer is converted into a voltmeter by connecting a resistance of 101 Ω in series. This voltmeter is connected as shown in figure(ii). Its reading is found to be 4/5 of the full scale reading. Find

(a) internal resistance r of the cell
(b) range of the ammeter and voltmeter
(c) full scale deflection current of the galvanometer



EXERCISE # III

Q.1 An electrical circuit is shown in the figure. Calculate the potential difference across the resistance of 400 ohm, as will be measured by the voltmeter V of resistance 400 ohm, either by applying Kirchhoff's rules or otherwise. [JEE'96, 6]



Q.2(i) A steady current flows in a metallic conductor of nonuniform cross-section. The quantity /quantities constant along the length of the conductor is / are : [JEE'97,1+2+5]

(A) current, electric field and drift speed
(B) drift speed only
(C) current and drift speed
(D) current only

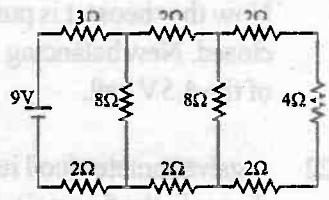
(ii) The dimension of electricity conductivity is ________.

(iii) Find the emf (E) & internal resistance (r) of a single battery which is equivalent to a parallel combination of two batteries of emfs V_1 & V_2 & internal resistances r_1 & r_2 respectively with their similar polarity connected to each other

Q.3 In the circuit shown in the figure, the current through :

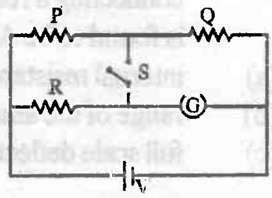
(A) the 3Ω resistor is 0.50 A
(B) the 3Ω resistor is 0.25 A
(C) 4 Ω resistor is 0.50 A
(D) the 4Ω resistor is 0.25 A

[JEE'98, 2]



Q.4 In the circuit shown, $P \neq R$, the reading of the galvanometer is same with switch S open or closed. Then

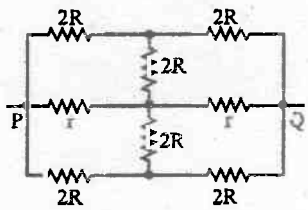
(A) $I_R = I_G$ (B) $I_P = I_G$ (C) $I_Q = I_G$ (D) $I_Q = I_R$ [JEE'99, 2]



Q.5 The effective resistance between the points P and Q of the electrical circuit shown in the figure is

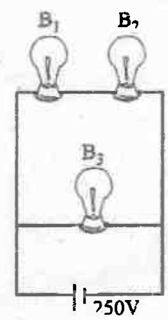
(A) $2Rr/(R+r)$
(B) $8R(R+r)/(3R+r)$
(C) $2r + 4R$
(D) $5R/2 + 2r$

[JEE 2002 (Scr), 3]

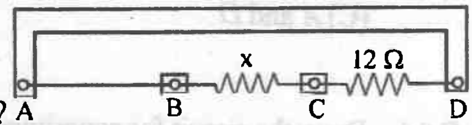


Q.6 A 100 W bulb B_1, and two 60 W bulbs B_2 and B_3, are connected to a 250 V source, as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. Then

(A) $W_1 > W_2 = W_3$
(B) $W_1 > W_2 > W_3$
(C) $W_1 < W_2 = W_3$
(D) $W_1 < W_2 < W_3$ [JEE 2002 (Scr), 3]



Q.7 A thin uniform wire AB of length 1 m, an unknown resistance X and a resistance of 12 Ω are connected by thick conducting strips, as shown in figure. A battery and a galvanometer (with a sliding jockey connected to it) are also available. Connections are to be made to measure the unknown resistance X using the principle of Wheatstone bridge. Answer the following question.

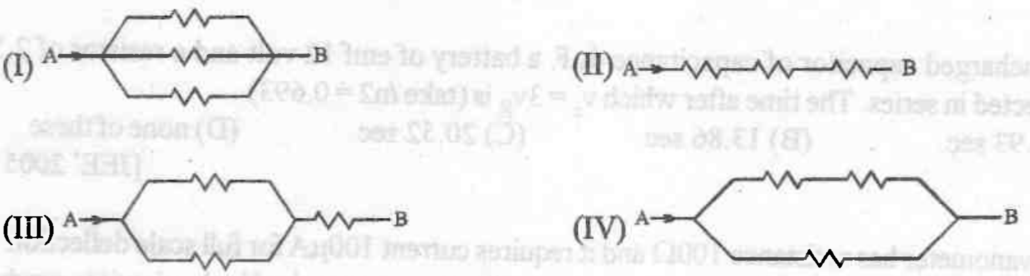


(a) Are there positive and negative terminals on the galvanometer?

(b) Copy the figure in your answer book and show the battery and the galvanometer (with jockey) connected at appropriate points.

(c) After appropriate connections are made, it is found that no deflection takes place in the galvanometer when the sliding jockey touches the wire at a distance of 60 cm from A. Obtain the value of resistance X. [JEE' 2002, 1 + 2 + 2]

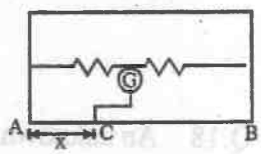
Q.8 Arrange the order of power dissipated in the given circuits, if the same current is passing through all circuits and each resistor is 'r' [JEE' 2003 (Scr)]



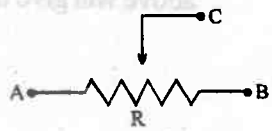
(A) $P_2 > P_3 > P_4 > P_1$ (B) $P_3 > P_2 > P_4 > P_1$ (C) $P_4 > P_3 > P_2 > P_1$ (D) $P_1 > P_2 > P_3 > P_4$

Q.9 In the given circuit, no current is passing through the galvanometer. If the cross-sectional diameter of AB is doubled then for null point of galvanometer the value of AC would [JEE' 2003 (Scr)]

(A) x (B) x/2 (C) 2x (D) None

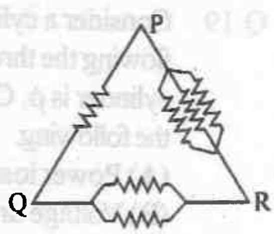


Q.10 How a battery is to be connected so that shown rheostat will behave like a potential divider? Also indicate the points about which output can be taken. [JEE' 2003]



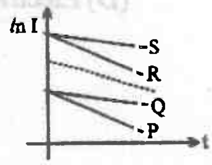
Q.11 Six equal resistances are connected between points P, Q and R as shown in the figure. Then the net resistance will be maximum between

(A) P and Q
(B) Q and R
(C) P and R
(D) any two points [JEE' 2004 (Scr)]

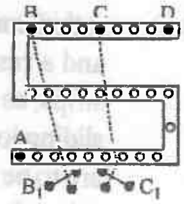


Q.12 In an RC circuit while charging, the graph of ln I versus time is as shown by the dotted line in the adjoining diagram where I is the current. When the value of the resistance is doubled, which of the solid curves best represents the variation of ln I versus time? [JEE' 2004 (Scr)]

(A) P (B) Q (C) R (D) S



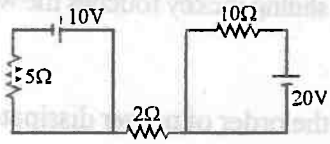
Q.13 For the post office box arrangement to determine the value of unknown resistance, the unknown resistance should be connected between [JEE' 2004 (Scr)]



(A) *B* and *C* (B) *C* and *D*
(C) *A* and *D* (D) B_1 and C_1

Q.14 Draw the circuit for experimental verification of Ohm's law using a source of variable D.C. voltage, a main resistance of 100 Ω, two galvanometers and two resistances of values 10^6 Ω and 10^{-3} Ω respectively. Clearly show the positions of the voltmeter and the ammeter. [JEE' 2004]

Q.15 In the figure shown the current through 2Ω resistor is



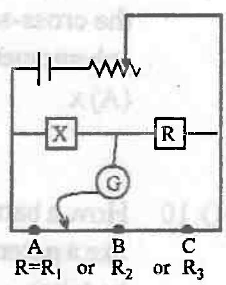
(A) 2 A (B) 0 A
(C) 4 A (D) 6 A

[JEE' 2005 (Scr)]

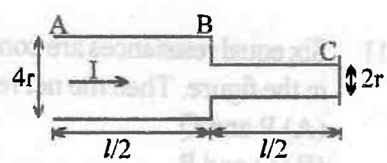
Q.16 An uncharged capacitor of capacitance 4μF, a battery of emf 12 volt and a resistor of 2.5 MΩ are connected in series. The time after which $v_c = 3v_R$ is (take $ln2 = 0.693$)
(A) 6.93 sec. (B) 13.86 sec. (C) 20.52 sec. (D) none of these
[JEE' 2005 (Scr)]

Q.17 A galvanometer has resistance 100Ω and it requires current 100μA for full scale deflection. A resistor 0.1Ω is connected to make it an ammeter. The smallest current required in the circuit to produce the full scale deflection is
(A) 1000.1 mA (B) 1.1 mA (C) 10.1 mA (D) 100.1 mA
[JEE' 2005 (Scr)]

Q.18 An unknown resistance X is to be determined using resistances R_1, R_2 or R_3. Their corresponding null points are A, B and C. Find which of the above will give the most accurate reading and why? [JEE 2005]



Q.19 Consider a cylindrical element as shown in the figure. Current flowing the through element is I and resistivity of material of the cylinder is ρ. Choose the correct option out the following.



(A) Power loss in second half is four times the power loss in first half
(B) Voltage drop in first half is twice of voltage drop in second half
(C) Current density in both halves are equal.
(D) Electric field in both halves is equal. [JEE 2006]

ANSWER KEY

EXERCISE # I

Q.1 1Ω Q.2 3.5 A Q.3 I = 2.5 A, V = 3.5 Volts Q.4 $\frac{22}{35}\Omega$

Q.5 12A, –20W. Q.6 $\sqrt{R_1R_2}$ Q.7 8/7 R Q.8 $\frac{3r}{5}$

Q.9 4Ω Q.10 1Ω Q.11 600Ω Q.12 1 V

Q.13 9Ω Q.14 46.67 cm Q.15 4 ohm Q.16 $\frac{10}{3}$ Ω, 5 Ω

Q.17 20 ohm Q.18 7.5 m, 8.75m, 6.25m Q.19 $R_1 = 0.0278\ \Omega$, $R_2 = 0.25\ \Omega$, $R_3 = 2.5\ \Omega$

EXERCISE # II

Q.1 (3/11)α Q.2 (a) $J_0A/3$; (b) $2J_0A/3$ Q.3 $\frac{R_2}{R_1} = \frac{3}{5}$

Q.4 (i) 10.52Ω ; (ii) 0.3125Ω Q.5 7/5 times the length of any side of the square

Q.6 (i) $\frac{(k-1)^2}{k}$; $\frac{k}{(k-1)}$ (ii) $\frac{\left((k-1)/k^2\right)V_0}{R^3}$ Q.7 $\frac{(2+\pi)a\,r}{8}$

Q.8 0.3Ω Q.9 4/9 kg/sec., 450 sec

Q.10 (i) $V_{ab} = -12$ V, (ii) 3 amp from b to a Q.11 $11+6\sqrt{2}$

Q.12 $R = \frac{\rho_0 L}{A}\left(1-\frac{1}{e}\right)$; $I = \frac{V_0 A}{\rho_0 L}\left(\frac{e}{e-1}\right)$; $V = \frac{V_0\left(e^{-x/L}-e^{-1}\right)}{1-e^{-1}}$

Q.13 $\frac{\varepsilon}{r+R_0(f-f^2)}$; for I_{max} f = 0, 1 ; I_{min} f = 1/2 Q.14 7.2 m Q.15 (a) 5/7 R, (b) 9R/14

Q.17 $-\frac{22}{9}$V Q.18 $\alpha_{eff} = \frac{5}{4}\alpha$ Q.19 1A Q.20 233.3Ω; 144V Q.21 (a) 6 m, (b) 1Ω

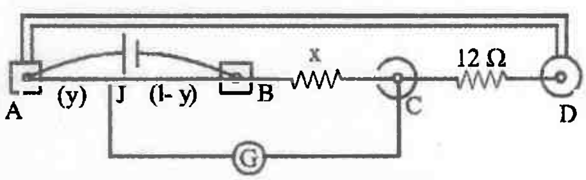
Q.22 (a) 1.01 W, (b) 0-5A, 0-10V, (c) 0.05 A

EXERCISE # III

Q.1 20/3 V Q.2 (i) D; (ii) $M^{-1}L^{-3}T^3A^2$; (iii) $\frac{V_1r_2+V_2r_1}{r_1+r_2}$, $\frac{r_1r_2}{r_1+r_2}$ Q.3 D

Q.4 A Q.5 A Q.6 D

Q.7 (a) No, (b)

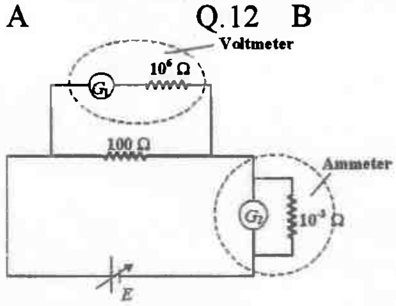


(c) 8 Ω Q.8 A Q.9 A

Q.10 Battery should be connected across A and B. Out put can be taken across the terminals A and C or B and C

Q.11 A Q.12 B Q.13 C

Q.14



Q.15 B Q.16 B Q.17 D

Q.18 This is true for $r_1 = r_2$; So R_2 given most accurate value Q.19 A

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

ELECTROMAGNETIC INDUCTION & ALTERNATING CURRENT

CONTENTS

KEY CONCEPTS

When a conductor is moved across a magnetic field, an electromotive force (emf) is produced in the conductor. If the conductors forms part of a closed circuit then the emf produced caused an electric current to flow round the circuit. Hence an emf (and thus a current) is induced in the conductor as a result of its movement across the magnetic field. This is known as "ELECTROMAGNETIC INDUCTION."

1. **MAGNETIC FLUX :**

$\phi = \vec{B} \cdot \vec{A} = BA\cos\theta$ weber for uniform $\vec{B}$.

$\phi = \int \vec{B} \cdot d\vec{A}$ for non uniform $\vec{B}$.

2. **FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION :**

(i) An induced emf is setup whenever the magnetic flux linking that circuit changes.

(ii) The magnitude of the induced emf in any circuit is proportional to the rate of change of the magnetic flux linking the circuit, $\varepsilon \propto \frac{d\phi}{dt}$.

3. **LENZ'S LAWS :**

The direction of an induced emf is always such as to oppose the cause producing it .

4. **LAW OF EMI :**

$e = -\frac{d\phi}{dt}$. The negative sign indicated that the induced emf opposes the change of the flux .

5. **EMF INDUCED IN A STRAIGHT CONDUCTOR IN UNIFORM MAGNETIC FIELD :**

$E = BLV\sin\theta$ volt where

B = flux density in wb/m^2 ; L = length of the conductor (m) ;
V = velocity of the conductor (m/s) ;
θ = angle between direction of motion of conductor & B .

6. **COIL ROTATION IN MAGNETIC FIELD SUCH THAT AXIS OF ROTATION IS PERPENDICULAR TO THE MAGNETIC FIELD :**

Instantaneous induced emf. $E = NAB\omega\sin\omega t = E_0\sin\omega t$, where
N = number of turns in the coil ; A = area of one turn ;
B = magnetic induction ; ω = uniform angular velocity of the coil ;
E_0 = maximum induced emf .

7. **SELF INDUCTION & SELF INDUCTANCE :**

When a current flowing through a coil is changed the flux linking with its own winding changes & due to the change in linking flux with the coil an emf is induced which is known as self induced emf & this phenomenon is known as self induction . This induced emf opposes the causes of Induction. The property of the coil or the circuit due to which it opposes any change of the current coil or the circuit is known as SELF - INDUCTANCE . It's unit is Henry .

Coefficient of Self inductance $L = \frac{\phi_s}{i}$ or $\phi_s = Li$

L depends only on ;

(i) shape of the loop &

(ii) medium

i = current in the circuit .

ϕ_s = magnetic flux linked with the circuit due to the current i .

self induced emf $e_s = \frac{d\phi_s}{dt} = -\frac{d}{dt}(Li) = -L\frac{di}{dt}$ (if L is constant)

8. MUTUAL INDUCTION :

If two electric circuits are such that the magnetic field due to a current in one is partly or wholly linked with the other, the two coils are said to be electromagnetically coupled circuits . Than any change of current in one produces a change of magnetic flux in the other & the latter opposes the change by inducing an emf within itself . This phenomenon is called **MUTUAL INDUCTION** & the induced emf in the latter circuit due to a change of current in the former is called **MUTUALLY INDUCED EMF** . The circuit in which the current is changed, is called the primary & the other circuit in which the emf is induced is called the secondary. The co-efficient of mutual induction (mutual inductance) between two electromagnetically coupled circuit is the magnetic flux linked with the secondary per unit current in the primary.

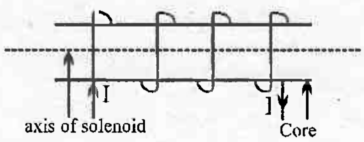
Mutual inductance = $M = \frac{\phi_m}{I_p} = \frac{\text{flux linked with secondary}}{\text{current in the primary}}$ mutually induced emf .

$E_m = \frac{d\phi_m}{dt} = -\frac{d}{dt}(MI) = -M\frac{dI}{dt}$ (If M is constant)

M depends on (1) geometery of loops (2) medium (3) orientation & distance of loops .

9. SOLENOID :

There is a uniform magnetic field along the axis the solenoid (ideal : length >> diameter)



$B = \mu ni$ where ;

μ = magnetic permeability of the core material ;

n = number of turns in the solenoid per unit length ;

i = current in the solenoid ;

Self inductance of a solenoid $L = \mu_0 n^2 A l$;

A = area of cross section of solenoid .

10. SUPER CONDUCTION LOOP IN MAGNETIC FIELD :

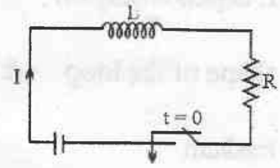
R = 0 ; ε = 0. Therefore ϕ_{total} = constant. Thus in a superconducting loop flux never changes. (or it opposes 100%)

11. (i) ENERGY STORED IN AN INDUCTOR :

$W = \frac{1}{2}LI^2$.

(ii) Energy of interation of two loops $U = I_1\phi_2 = I_2\phi_1 = MI_1I_2$, where M is mutual inductance .

12. GROWTH OF A CURRENT IN AN L – R CIRCUIT :



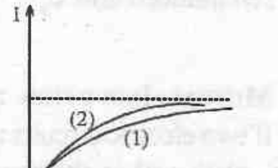
$I = \frac{E}{R}(1 - e^{-Rt/L})$. [If initial current = 0]

$\frac{L}{R}$ = time constant of the circuit .

$I_0 = \frac{E}{R}$.

(i) L behaves as open circuit at t = 0 [If $i = 0$]

(ii) L behaves as short circuit at $t = \infty$ always .

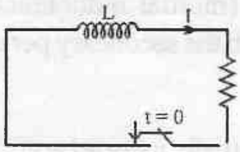


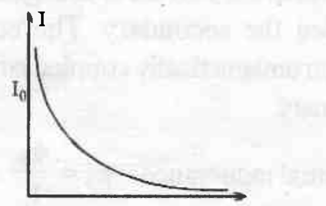
Curve (1) $\longrightarrow$ $\frac{L}{R}$ Large

Curve (2) $\longrightarrow$ $\frac{L}{R}$ Small

13. DECAY OF CURRENT :

Initial current through the inductor = I_0 ; Current at any instant $i = I_0 e^{-Rt/L}$

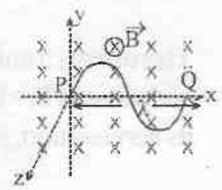




EXERCISE–I

Q.1 The horizontal component of the earth's magnetic field at a place is 3×10^{-4} T and the dip is $\tan^{-1}(4/3)$. A metal rod of length 0.25 m placed in the north-south position is moved at a constant speed of 10cm/s towards the east. Find the e.m.f. induced in the rod.

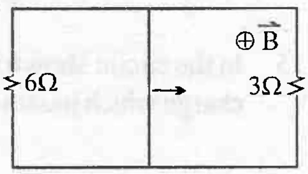
Q.2 A wire forming one cycle of sine curve is moved in x-y plane with velocity $\vec{V} = V_x\hat{i} + V_y\hat{j}$. There exist a magnetic field $\vec{B} = -B_0\hat{k}$. Find the motional emf develop across the ends PQ of wire.



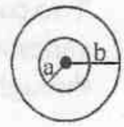
Q.3 A conducting circular loop is placed in a uniform magnetic field of 0.02 T, with its plane perpendicular to the field. If the radius of the loop starts shrinking at a constant rate of 1.0 mm/s, then find the emf induced in the loop, at the instant when the radius is 4 cm.

Q.4 Find the dimension of the quantity $\frac{L}{RCV}$, where symbols have usual meaining.

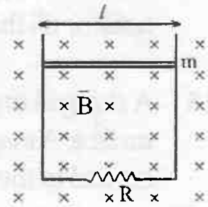
Q.5 A rectangular loop with a sliding connector of length l = 1.0 m is situated in a uniform magnetic field B = 2T perpendicular to the plane of loop. Resistance of connector is r = 2Ω. Two resistances of 6Ω and 3Ω are connected as shown in figure. Find the external force required to keep the connector moving with a constant velocity v = 2m/s.



Q.6 Two concentric and coplanar circular coils have radii a and b(>>a) as shown in figure. Resistance of the inner coil is R. Current in the outer coil is increased from 0 to i, then find the total charge circulating the inner coil.

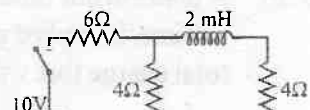


Q.7 A horizontal wire is free to slide on the vertical rails of a conducting frame as shown in figure. The wire has a mass m and length l and the resistance of the circuit is R. If a uniform magnetic field B is directed perpendicular to the frame, then find the terminal speed of the wire as it falls under the force of gravity.

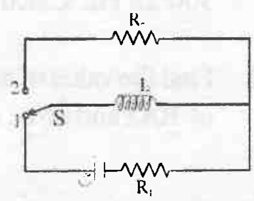


Q.8 A metal rod of resistance 20Ω is fixed along a diameter of a conducting ring of radius 0.1 m and lies on x-y plane. There is a magnetic field $\vec{B} = (50T)\hat{k}$. The ring rotates with an angular velocity ω = 20 rad/sec about its axis. An external resistance of 10Ω is connected across the centre of the ring and rim. Find the current through external resistance.

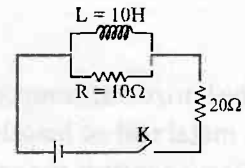
Q.9 In the given current, find the ratio of i_1 to i_2 where i_1 is the initial (at t = 0) current and i_2 is steady state (at t = ∞) current through the battery.



Q.10 In the circuit shown, initially the switch is in position 1 for a long time. Then the switch is shifted to position 2 for a long time. Find the total heat produced in R_2.



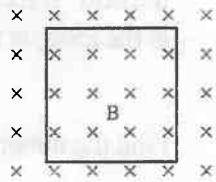
Q.11 Two resistors of 10Ω and 20Ω and an ideal inductor of 10H are connected to a 2V battery as shown. The key K is shorted at time $t = 0$. Find the initial ($t = 0$) and final ($t \to \infty$) currents through battery.



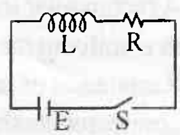
Q.12 There exists a uniform cylindrically symmetric magnetic field directed along the axis of a cylinder but varying with time as $B = kt$. If an electron is released from rest in this field at a distance of 'r' from the axis of cylinder, its acceleration, just after it is released would be (e and m are the electronic charge and mass respectively)

Q.13 An emf of 15 volt is applied in a circuit containing 5 H inductance and $10\ \Omega$ resistance. Find the ratio of the currents at time $t = \infty$ and $t = 1$ second.

Q.14 A uniform magnetic field of 0.08 T is directed into the plane of the page and perpendicular to it as shown in the figure. A wire loop in the plane of the page has constant area $0.010\ m^2$. The magnitude of magnetic field decrease at a constant rate of $3.0 \times 10^{-4}\ Ts^{-1}$. Find the magnitude and direction of the induced emf in the loop.



Q.15 In the circuit shown in figure switch S is closed at time $t = 0$. Find the charge which passes through the battery in one time constant.

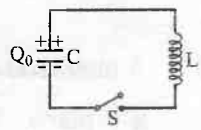


Q.16 Two coils, 1 & 2, have a mutual inductance = M and resistances R each. A current flows in coil 1, which varies with time as: $I_1 = kt^2$, where K is a constant and 't' is time. Find the total charge that has flown through coil 2, between $t = 0$ and $t = T$.

Q.17 In a L–R decay circuit, the initial current at $t = 0$ is I. Find the total charge that has flown through the resistor till the energy in the inductor has reduced to one–fourth its initial value.

Q.18 A charged ring of mass m = 50 gm, charge 2 coulomb and radius R = 2m is placed on a smooth horizontal surface. A magnetic field varying with time at a rate of (0.2 t) Tesla/sec is applied on to the ring in a direction normal to the surface of ring. Find the angular speed attained in a time $t_1 = 10$ sec.

Q.19 A capacitor C with a charge Q_0 is connected across an inductor through a switch S. If at $t = 0$, the switch is closed, then find the instantaneous charge q on the upper plate of capacitor.



Q.20 A uniform but time varying magnetic field $B = Kt - C$; $(0 < t < C/K)$, where K and C are constants and t is time, is applied perpendicular to the plane of the circular loop of radius 'a' and resistance R. Find the total charge that will pass around the loop.

Q.21 A coil of resistance 300Ω and inductance 1.0 henry is connected across an alternating voltage of frequency $300/2\pi$ Hz. Calculate the phase difference between the voltage and current in the circuit.

Q.22 Find the value of an inductance which should be connected in series with a capacitor of $5\ \mu F$, a resistance of 10Ω and an ac source of 50 Hz so that the power factor of the circuit is unity.

Q.23 In an L-R series A.C circuit the potential difference across an inductance and resistance joined in series are respectively 12 V and 16V. Find the total potential difference across the circuit.

Q.24 When 100 volt D.C. is applied across a coil, a current of one ampere flows through it, when 100 V ac of 50 Hz is applied to the same coil, only 0.5 amp flows. Calculate the resistance and inductance of the coil.

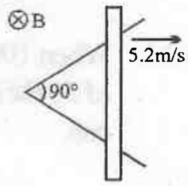
Q.25 A 50W, 100V lamp is to be connected to an ac mains of 200V, 50Hz. What capacitance is essential to be put in seirs with the lamp.

List of recommended questions from I.E. Irodov.

3.288 to 3.299, 3.301 to 3.309, 3.311, 3.313, 3.315, 3.316, 3.326 to 3.329, 3.331, 3.333 to 3.335, 4.98, 4.99, 4.100, 4.134, 4.135, 4.121, 4.124, 4.125, 4.126, 4.136, 4.137, 4.141, 4.144

EXERCISE–II

Q.1 Two straight conducting rails form a right angle where their ends are joined. A conducting bar contact with the rails starts at vertex at the time t = 0 & moves symmetrically with a constant velocity of 5.2 m/s to the right as shown in figure. A 0.35 T magnetic field points out of the page. Calculate:

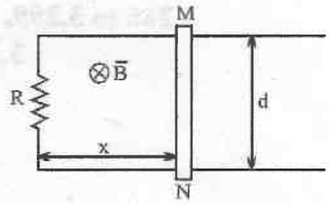


(i) The flux through the triangle by the rails & bar at t = 3.0 s.

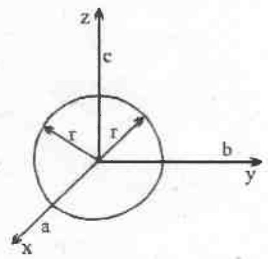
(ii) The emf around the triangle at that time.

(iii) In what manner does the emf around the triangle vary with time.

Q.2 Two long parallel rails, a distance l apart and each having a resistance λ per unit length are joined at one end by a resistance R. A perfectly conducting rod MN of mass m is free to slide along the rails without friction. There is a uniform magnetic field of induction B normal to the plane of the paper and directed into the paper. A variable force F is applied to the rod MN such that, as the rod moves, a constant current i flows through R. Find the velocity of the rod and the applied force F as function of the distance x of the rod from R



Q.3 A wire is bent into 3 circular segments of radius r = 10 cm as shown in figure. Each segment is a quadrant of a circle, ab lying in the xy plane, bc lying in the yz plane & ca lying in the zx plane.



(i) if a magnetic field B points in the positive x direction, what is the magnitude of the emf developed in the wire, when B increases at the rate of 3 mT/s ?

(ii) what is the direction of the current in the segment bc.

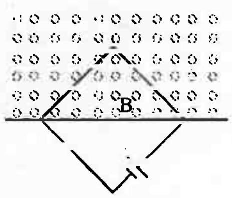
Q.4 Consider the possibility of a new design for an electric train. The engine is driven by the force due to the vertical component of the earths magnetic field on a conducting axle. Current is passed down one coil, into a conducting wheel through the axle, through another conducting wheel & then back to the source via the other rail.

(i) what current is needed to provide a modest 10 – KN force ? Take the vertical component of the earth's field be 10 μT & the length of axle to be 3.0 m.

(ii) how much power would be lost for each Ω of resistivity in the rails ?

(iii) is such a train unrealistic ?

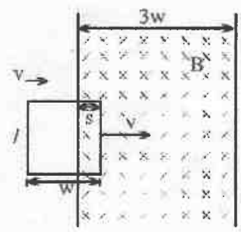
Q.5 A square wire loop with 2 m sides in perpendicular to a uniform magnetic field, with half the area of the loop in the field. The loop contains a 20 V battery with negligible internal resistance. If the magnitude of the field varies with time according to B = 0.042 – 0.87 t, with B in tesla & t in sec.



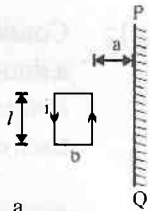
(i) What is the total emf in the circuit ?

(ii) What is the direction of the current through the battery ?

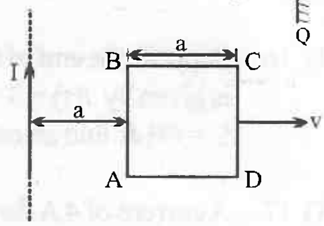
Q.6 A rectangular loop of dimensions l & w and resistance R moves with constant velocity V to the right as shown in the figure. It continues to move with same speed through a region containing a uniform magnetic field B directed into the plane of the paper & extending a distance 3 W. Sketch the flux, induced emf & external force acting on the loop as a function of the distance.



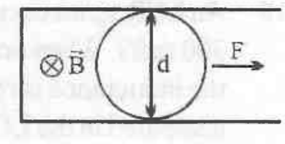
Q.7 A rectangular loop with current I has dimension as shown in figure. Find the magnetic flux ϕ through the infinite region to the right of line PQ.



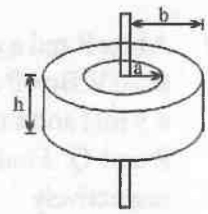
Q.8 A square loop of side 'a' & resistance R moves with a uniform velocity v away from a long wire that carries current I as shown in the figure. The loop is moved away from the wire with side AB always parallel to the wire. Initially, distance between the side AB of the loop & wire is 'a'. Find the work done when the loop is moved through distance 'a' from the initial position.



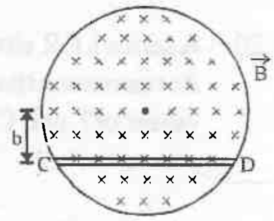
Q.9 Two long parallel conducting horizontal rails are connected by a conducting wire at one end. A uniform magnetic field B exists in the region of space. A light uniform ring of diameter d which is practically equal to separation between the rails, is placed over the rails as shown in the figure. If resistance of ring is λ per unit length, calculate the force required to pull the ring with uniform velocity v.



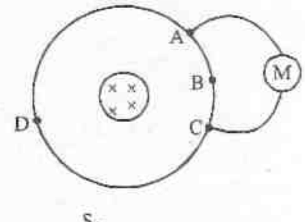
Q.10 A long straight wire is arranged along the symmetry axis of a toroidal coil of rectangular cross–section, whose dimensions are given in the figure. The number of turns on the coil is N, and permeability of the surrounding medium is unity. Find the amplitude of the emf induced in this coil, if the current $i = i_m \cos \omega t$ flows along the straight wire.



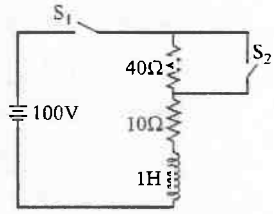
Q.11 A uniform magnetic field $\vec{B}$ fills a cylindrical volumes of radius R. A metal rod CD of length l is placed inside the cylinder along a chord of the circular cross-section as shown in the figure. If the magnitude of magnetic field increases in the direction of field at a constant rate dB/dt, find the magnitude and direction of the EMF induced in the rod.



Q.12 A variable magnetic field creates a constant emf E in a conductor ABCDA. The resistances of portion ABC, CDA and AMC are R_1, R_2 and R_3 respectively. What current will be shown by meter M? The magnetic field is concentrated near the axis of the circular conductor.



Q.13 In the circuit shown in the figure the switched S_1 and S_2 are closed at time t = 0. After time t = (0.1) ln 2 sec, switch S_2 is opened. Find the current in the circuit at time t = (0.2) ln 2 sec.



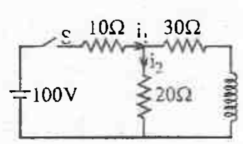
Q.14 Find the values of i_1 and i_2

(i) immediately after the switch S is closed.

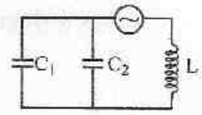
(ii) long time later, with S closed.

(iii) immediately after S is open.

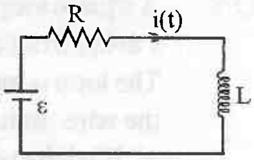
(iv) long time after S is opened.



Q.15 Consider the circuit shown in figure. The oscillating source of emf deliver a sinusoidal emf of amplitude e_{max} and frequency ω to the inductor L and two capacitors C_1 and C_2. Find the maximum instantaneous current in each capacitor.



Q.16 Suppose the emf of the battery, the circuit shown varies with time t so the current is given by $i(t) = 3 + 5t$, where i is in amperes & t is in seconds. Take R = 4Ω, L = 6H & find an expression for the battery emf as function of time.



Q.17 A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12V, 50 rad/s ac source a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also find the power developed in the circuit if a 2500 μF capacitor is connected in series with the coil.

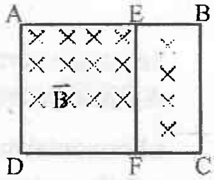
Q.18 An LCR series circuit with 100Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current and the power dissipated in the LCR circuit.

Q.19 A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source at 10 V. Box P contains a capacitance of 1 μF in series with a resistance of 32Ω coil Q has a self-inductance 4.9 mH and a resistance of 68Ω series. The frequency is adjusted so that the maximum current flows in P and Q. Find the impedance of P and Q at this frequency. Also find the voltage across P and Q respectively.

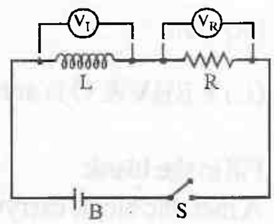
Q.20 A series LCR circuit containing a resistance of 120Ω has angular resonance frequency 4×10^5 rad s^{-1}. At resonance the voltages across resistance and inductance are 60 V and 40 V respectively. Find the values of L and C. At what frequency the current in the circuit lags the voltage by 45°?

EXERCISE–III

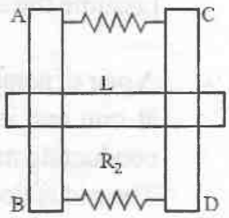
Q.1 A rectangular frame ABCD made of a uniform metal wire has a straight connection between E & F made of the same wire as shown in the figure. AEFD is a square of side 1 m & EB = FC = 0.5 m. The entire circuit is placed in a steadily increasing uniform magnetic field directed into the place of the paper & normal to it. The rate of change of the magnetic field is 1 T/s, the resistance per unit length of the wire is 1 Ω/m. Find the current in segments AE, BE & EF. [JEE '93, 5]



Q.2 An inductance L, resistance R, battery B and switch S are connected in series. Voltmeters V_L and V_R are connected across L and R respectively. When switch is closed:
(A) The initial reading in V_L will be greater than in V_R.
(B) The initial reading in V_L will be lesser than V_R.
(C) The initial readings in V_L and V_R will be the same.
(D) The reading in V_L will be decreasing as time increases. [JEE'93, 2]



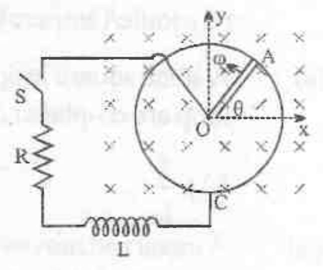
Q.3 Two parallel vertical metallic rails AB & CD are separated by 1 m. They are connected at the two ends by resistance R_1 & R_2 as shown in the figure. A horizontally metallic bar L of mass 0.2 kg slides without friction, vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0.6T perpendicular to the plane of the rails, it is observed that when the terminal velocity is attained, the power dissipated in R_1 & R_2 are 0.76 W & 1.2 W respectively. Find the terminal velocity of bar L & value R_1 & R_2. [JEE '94, 6]



Q.4 Two different coils have self inductance 8mH and 2mH. The current in one coil is increased at a constant rate. The current in the second coild is also increased at the same constant. At a certain instant of time, the power given to the two coils is the same. At that time the current, the induced voltage and the energy stored in the first coil are I_1, V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are I_2, v_2 and W_2 respectively. Then: [JEE'94, 2]

(A) $\frac{I_1}{I_2} = \frac{1}{4}$ (B) $\frac{I_1}{I_2} = 4$ (C) $\frac{W_2}{W_1} = 4$ (D) $\frac{V_2}{V_1} = \frac{1}{4}$

Q.5 A metal rod OA of mass m & length r is kept rotating with a constant angular speed ω in a vertical plane about a horizontal axis at the end O. The free end A is arranged to slide without friction along a fixed conducting circular ring in the same plane as that of rotation. A uniform & constant magnetic induction $\bar{B}$ is applied perpendicular & into the plane of rotation as shown in figure. An inductor L and an external resistance R are connected through a switch S between the point O & a point C on the ring to form an electrical circuit. Neglect the resistance of the ring and the rod. Initially, the switch is open.

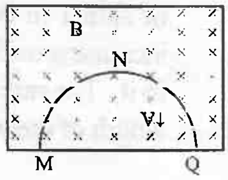


(a) What is the induced emf across the terminals of the switch?
(b) (i) Obtain an expression for the current as a function of time after switch S is closed.
(ii) Obtain the time dependence of the torque required to maintain the constant angular speed, given that the rod OA was along the positive X-axis at t = 0. [JEE '95, 10]

Q.6 A solenoid has an inductance of 10 Henry & a resistance of 2 Ω. It is connected to a 10 volt battery. How long will it take for the magnetic energy to reach 1/4 of its maximum value ?

[JEE '96, 3]

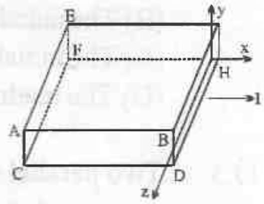
Q.7 Select the correct alternative.
A thin semicircular conducting ring of radius R is falling with its plane vertical in a horizontal magnetic induction $\vec{B}$. At the position MNQ the speed of the ring is v & the potential difference developed across the ring is :



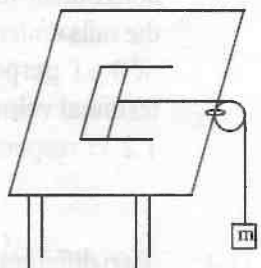
(A) zero (B) $\frac{Bv\pi R^2}{2}$ & M is at higher potential
(C) π RBV & Q is at higher potential (D) 2 RBV & Q is at higher potential

[JEE'96, 2]

Q.8 Fill in the blank.
A metallic block carrying current I is subjected to a uniform magnetic induction $B\hat{j}$. The moving charges experience a force $\vec{F}$ given by ______ which results in the lowering of the potential of the face
[assume the speed of the carrier to be v] [JEE '96, 2]



Q.9 A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rails is L. A conducting massless rod of resistance R can slide on the rails frictionlessly. The rod is tied to a massless string which passes over a pulley fixed to the edge of the table. A mass m, tied to the other end of the string hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest, calculate:



(i) the terminal velocity achieved by the rod.
(ii) the acceleration of the mass at the instant when the velocity of the rod is half the terminal velocity.

[JEE '97, 5]

Q.10 A current $i = 3.36\,(1 + 2t) \times 10^{-2}$ A increases at a steady rate in a long straight wire. A small circular loop of radius 10^{-3} m is in the plane of the wire & is placed at a distance of 1 m from the wire. The resistance of the loop is 8.4×10^{-2} Ω. Find the magnitude & the direction of the induced current in the loop.

[REE '98, 5]

Q.11 Select the correct alternative(s). [JEE '98, 3 × 2 = 6 ,4×2=8]

(i) The SI unit of inductance, the Henry, can be written as :
(A) weber/ampere (B) volt – second/ampere
(C) joule/(ampere)^2 (D) ohm – second

(ii) A small square loop of wire of side l is placed inside a large square loop of wire of side L(L >> l). The loop are co-planar & their centres coincide. The mutual inductance of the system is proportional to :
(A) $\frac{\ell}{L}$ (B) $\frac{\ell^2}{L}$ (C) $\frac{L}{\ell}$ (D) $\frac{L^2}{\ell}$

(iii) A metal rod moves at a constant velocity in a direction perpendicular to its length. A constant, uniform magnetic field exists in space in a direction perpendicular to the rod as well as its velocity. Select the correct statement(s) from the following
(A) the entire rod is at the same electric potential
(B) there is an electric field in the rod
(C) the electric potential is highest at the centre of the rod & decreases towards its ends
(D) the electric potential is lowest at the centre of the rod & increases towards its ends.

(iv) An inductor of inductance 2.0mH,is connected across a charged capacitor of capacitance 5.0μF,and the resulting LC circuit is set oscillating at its natural frequency. Let Q denote the instantaneous charge on the capacitor, and I the current in the circuit. It is found that the maximum value of Q is 200 μC.

(a) when Q=100μC,what is the value of $|dI/dt|$?

(b) when Q=200 μC ,what is the value of I ?

(c) Find the maximum value of I.

(d) when I is equal to one half its maximum value, what is the value of $|Q|$

Q.12 Two identical circular loops of metal wire are lying on a table without touching each other. Loop-A carries a current which increases with time. In response, the loop-B [JEE '99]

(A) remains stationary
(B) is attracted by the loop-A
(C) is repelled by the loop-A
(D) rotates about its CM, with CM fixed

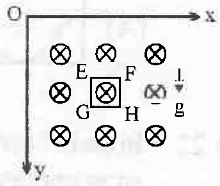
Q.13 A coil of inductance 8.4 mH and resistance 6Ω is connected to a 12V battery. The current in the coil is 1.0 A at approximately the time

(A) 500 s (B) 20 s (C) 35 ms (D) 1 ms [JEE '99]

Q.14 A circular loop of radius R, carrying current I, lies in x-y plane with its centre at origin. The total magnetic flux through x-y plane is

(A) directly proportional to I
(B) directly proportional to R
(C) directly proportional to R^2
(D) zero [JEE '99]

Q.15 A magnetic field $B = (B_0 y / a)\ k$ is into the plane of paper in the +z direction. B_0 and a are positive constants. A square loop EFGH of side a, mass m and resistance R, in x-y plane, starts falling under the influence of gravity. Note the directions of x and y axes in the figure. Find



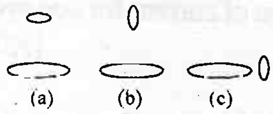
(a) the induced current in the loop and indicate its direction,

(b) the total Lorentz force acting on the loop and indicate its direction,

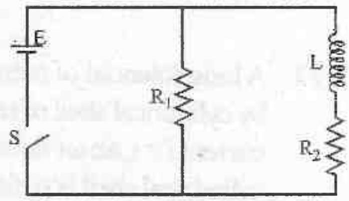
(c) an expression for the speed of the loop, $v(t)$ and its terminal value. [JEE '99]

Q.16 Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be

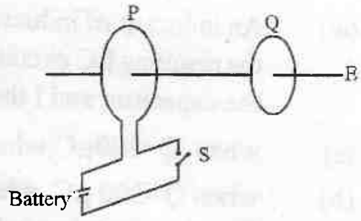
(A) maximum in situation (a)
(B) maximum in situation (b)
(C) maximum in situation (c)
(D) the same in all situations [JEE '2001, (Scr)]



Q.17 An inductor of inductance L = 400 mH and resistors of resistances $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of e.m.f. E = 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at time t = 0. What is the potential drop across L as a function of time? After the steady state is reached, the switch is opened. What is the direction and the magnitude of current through R_1 as a function of time? [JEE '2001]



Q.18 As shown in the figure, P and Q are two coaxial conducting loops separated by some distance. When the switch S is closed, a clockwise current I_P flows in P (as seen by E) and an induced current I_{Q1} flows in Q. The switch remains closed for a long time. When S is opened, a current I_{Q2} flows in Q. Then the directions of I_{Q1} adn I_{Q2} (as seen by E) are:

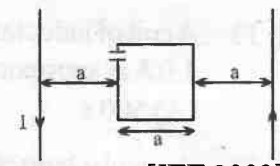


(A) respectively clockwise and anti-clockwise (B) both clockwise
(C) both anti-clockwise (D) respectively anti-clockwise and clockwise

[JEE 2002(Scr), 3]

Q.19 A short -circuited coil is placed in a time varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be [JEE 2002(Scr), 3]
(A) halved (B) the same (C) doubled (D) quadrupled

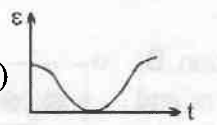
Q.20 A square loop of side 'a' with a capacitor of capacitance C is located between two current carrying long parallel wires as shown. The value of I in the is given as $I = I_0 \sin\omega t$.

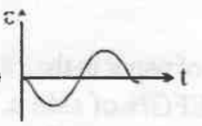


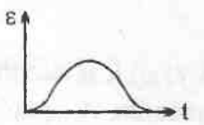
(a) calculate maximum current in the square loop.
(b) Draw a graph between charge on the lower plate of the capacitor v/s time. [JEE 2003]

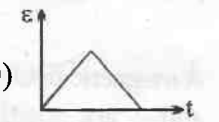
Q.21 The variation of induced emf (ε) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as



(A) 

(B) 

(C) 

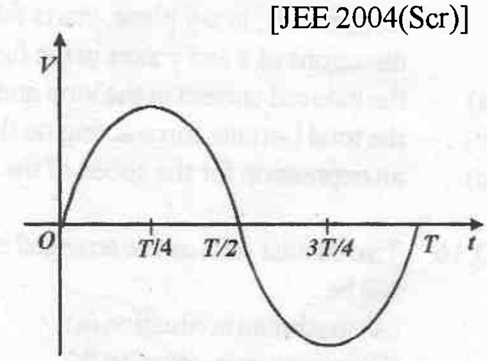
(D) 

[JEE 2004(Scr)]

Q.22 In an LR series circuit, a sinusoidal voltage $V = V_0 \sin \omega t$ is applied. It is given that L = 35 mH, R = 11 Ω,

$V_{rms} = 220$ V, $\frac{\omega}{2\pi} = 50$ Hz and $\pi = 22/7$. Find

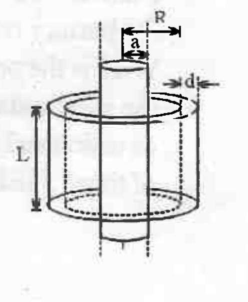
the amplitude of current in the steady state and obtain the phase difference between the current and the voltage. Also plot the variation of current for one cycle on the given graph. [JEE 2004]



Q.23 An infinitely long cylindrical conducting rod is kept along + Z direction. A constant magnetic field is also present in + Z direction. Then current induced will be
(A) 0 (B) along +z direction
(C) along clockwise as seen from + Z (D) along anticlockwise as seen from + Z

[JEE' 2005 (Scr)]

Q. 24 A long solenoid of radius a and number of turns per unit length n is enclosed by cylindrical shell of radius R, thickness d (d <<R) and length L. A variable current $i = i_0 \sin \omega t$ flows through the coil. If the resistivity of the material of cylindrical shell is ρ, find the induced current in the shell.



[JEE 2005]

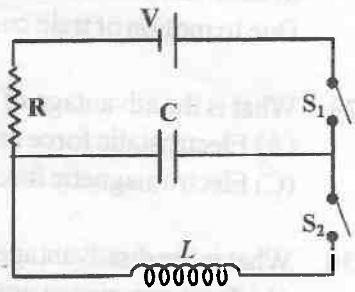
Q.25 In the given diagram, a line of force of a particular force field is shown. Out of the following options, it can never represent



(A) an electrostatic field
(B) a magnetostatic field
(C) a gravitational field of a mass at rest
(D) an induced electric field [JEE 2006]

Comprehension –I

The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor 'L' by closing switch S_2 and opening S_1.



Q.26 Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then
(A) after time interval τ, charge on the capacitor is CV/2
(B) after time interval 2τ, charge on the capacitor is $CV(1-e^{-2})$
(C) the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged.
(D) after time interval 2τ, charge on the capacitor is $CV(1-e^{-1})$ [JEE 2006]

Q.27 After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then,
(A) at t = 0, energy stored in the circuit is purely in the form of magnetic energy
(B) at any time t > 0, current in the circuit is in the same direction
(C) at t > 0, there is no exchange of energy between the inductor and capacitor
(D) at any time t > 0, instantaneous current in the circuit may $V\sqrt{\frac{C}{L}}$ [JEE 2006]

Q.28 If the total charge stored in the LC circuit is Q_0, then for t > 0

(A) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} + \frac{t}{\sqrt{LC}}\right)$

(B) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} - \frac{t}{\sqrt{LC}}\right)$

(C) the charge on the capacitor is $Q = -LC\frac{d^2Q}{dt^2}$

(D) the charge on the capacitor is $Q = -\frac{1}{\sqrt{LC}}\frac{d^2Q}{dt^2}$ [JEE 2006]

Comprehension –IV

Magler Train: This train is based on the Lenz law and phenomena of electromagnetic induction. In this there is a coil on a railway track and magnet on the base of train. So as train is deviated then as is move down coil on track repel it and as it move up then coil attract it.

Disadvantage of magler train is that as it slow down the forces decreases and as it moves forward so due to Lenz law coil attract it backward.

Due to motion of train current induces in the coil of track which levitate it.

Q.29 What is the advantage of the train? [JEE 2006]

(A) Electrostatic force draws the train
(B) Gravitational force is zero.
(C) Electromagnetic force draws the train
(D) Dissipative force due to friction are absent

Q.30 What is the disadvantage of the train?

(A) Train experience upward force due to Lenz's law.
(B) Friction force create a drag on the train.
(C) Retardation
(D) By Lenz's law train experience a drag [JEE 2006]

Q.31 Which force causes the train to elevate up

(A) Electrostatic force
(B) Time varying electric field
(C) magnetic force
(D) Induced electric field [JEE 2006]

Q.32 Match the following Columns

Column 1	Column 2
(A) Dielectric ring uniformly charged	(P) Time independent electrostatic field out of system
(B) Dielectric ring uniformly charged rotating with angular velocity .	(Q) Magnetic field
(C) Constant current in ring i_0	(R) Induced electric field
(D) Current $i = i_0 \cos \omega t$ in ring	(S) Magnetic moment

[JEE 2006]

ANSWER KEY

EXERCISE–I

Q.1 $10\,\mu V$ Q.2 $\lambda V_y B_0$ Q.3 $5.0\,\mu V$ Q.4 I^{-1} Q.5 2 N

Q.6 $\frac{\mu_0 i a^2 \pi}{2Rb}$ Q.7 $\frac{mgR}{B^2 l^2}$ Q.8 $\frac{1}{3}A$ Q.9 0.8 Q.10 $\frac{LE^2}{2R^2}$

Q.11 $\frac{1}{15}A, \frac{1}{10}A$

Q.12 $\frac{erk}{2m}$ directed along tangent to the circle of radius r, whose centre lies on the axis of cylinder.

Q.13 $\frac{e^2}{e^2-1}$ Q.14 $3\mu V$, clockwise Q.15 $\frac{EL}{eR^2}$ Q.16 $kMT^2/(R)$ Q.17 $LI/2R$

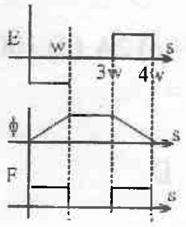
Q.18 200 rad/sec Q.19 $q = Q_0 \sin\left(\sqrt{\frac{1}{LC}}\,t + \frac{\pi}{2}\right)$ Q.20 $C\pi a^2/R$ Q.21 $\pi/4$

Q.22 $\frac{20}{\pi^2} \cong 2H$ Q.23 20 V Q.24 R = 100W, $\sqrt{3}/\pi$ Hz Q.25 $C = 9.2\,\mu F$

EXERCISE–II

Q.1 (i) $85.22\,Tm^2$; (ii) 56.8 V; (iii) linearly Q.2 $\frac{I(R+2\lambda x)}{Bd}, \frac{2I^2 m\lambda(R+2\lambda x)}{B^2 d^2} + BId$

Q.3 (i) 2.4×10^{-5} V (ii) from c to b Q.4 (i) 3.3×10^8 A, (ii) 1.0×10^{17} W, (iii) totally unrealistic

Q.5 21.74 V, anticlockwise Q.6 

Q.7 $\phi = \frac{\mu_0}{2\pi} IL\, ln \frac{a+b}{a}$

Q.8 $\frac{\mu_0^2 I^2 a^2 V}{4\pi^2 R}\left[\frac{2}{3a} + \frac{2}{a}\ell n\frac{3}{4}\right] = \frac{\mu_0^2 I^2 aV}{2\pi^2 R}\left[\frac{1}{3} + \ell n\frac{3}{4}\right]$ Q.9 $\frac{4B^2 vd}{\pi\lambda}$ Q.10 $\frac{\mu_0 h\omega i_m N}{2\pi}\, ln\frac{b}{a}$

Q.11 $\frac{l}{2}\frac{dB}{dt}\sqrt{R^2-\frac{l^2}{4}}$ Q.12 $\frac{E R_1}{R_1R_2+R_2R_3+R_3R_1}$ Q.13 67/32 A

Q.14 (i) $i_1 = i_2 = 10/3$ A, (ii) $i_1 = 50/11$ A ; $i_2 = 30/11$ A, (iii) $i_1 = 0$, $i_2 = 20/11$ A, (iv) $i_1 = i_2 = 0$

Q.15 $C_2=\frac{\varepsilon_{max}}{\left(1+\frac{C_1}{C_2}\right)\left(\omega L-\frac{1}{\omega(C_1+C_2)}\right)}$; $C_1=\frac{\varepsilon_{max}}{\frac{C_2}{C_1}\left(1+\frac{C_1}{C_2}\right)\left(\omega L-\frac{1}{\omega(C_1+C_2)}\right)}$ Q.16 42 + 20t volt

Q.17 0.08 H, 17.28 W Q.18 2A, 400W Q.19 77Ω, 97.6Ω, 7.7V, 9.76V

Q.20 0.2 mH, $\frac{1}{32}$ μF, 8×10^5 rad/s

EXERCISE–III

Q.1 $I_{EA}=\frac{7}{22}$ A, $I_{BE}=\frac{3}{11}$ A ; $i_{FE}=\frac{1}{22}$ A Q.2 A, D Q.3 V = 1 ms^{-1}, $R_1 = 0.47\ \Omega$, $R_2 = 0.30\ \Omega$

Q.4 ACD

Q.5 (a) $E=\frac{1}{2}B\omega r^2$ (b) (i) $I=\frac{B\omega r^2\left[1-e^{-Rt/L}\right]}{2R}$, (ii) $\tau=\frac{mgr}{2}\cos\omega t+\frac{\omega B^2r^4}{4R}(1-e^{-Rt/L})$

Q.6 $t=\frac{L}{R}\ln 2 = 3.47$ sec Q.7 D Q.8 $evB\hat{k}$, ABDC

Q.9 (i) $V_{terminal}=\frac{mgR}{B^2Z^2}$; (ii) $\frac{g}{2}$ Q.10 $1.6\,\pi \times 10^{-13}$ A = 50.3 pA

Q.11 (i) A, B, C, D, (ii) B, (iii) B, (iv) (a) 10^4 A/s (b) 0 (c) 2A (d) $100\sqrt{3}$ μC

Q.12 C Q.13 D Q.14 D

Q.15 (a) $i=\frac{B_0 av}{R}$ in anticlockwise direction, v = velocity at time t, (b) $F_{nett}=B_0^2a^2V/R$,

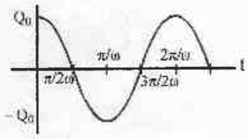
(c) $V=\frac{mgR}{B_0^2a^2}\left(1-e^{-\frac{B_0^2a^2t}{mR}}\right)$

Q.16 A

Q.17 $12e^{-5t}$, $6e^{-10t}$

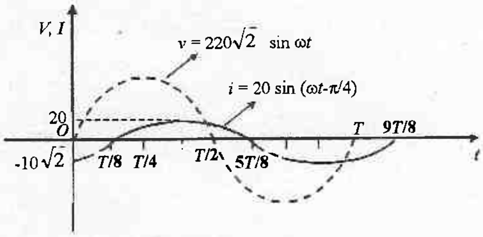
Q.18 D

Q.19 B

Q.20 (a) $I_{max} = \frac{\mu_0 a}{\pi} CI_0\omega^2 ln2$, (b) 

Q.21 B

Q.22 20 A, $\frac{\pi}{4}$, $\therefore$ Steady state current $i = 20\sin\pi\left(100t - \frac{1}{4}\right)$



Q.23 A

Q.24 $I = \frac{(\mu_0 n i_0 \omega \cos\omega t)\pi a^2 (Ld)}{\rho 2\pi R}$

Q.25 A,C

Q.26 B

Q.27 D

Q.28 C

Q.29 D

Q.30 D

Q.31 C

Q.32 (A) P; (B) P, Q, S; (C) Q,S ; (D) Q, R, S

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

ELECTROMAGNETIC INDUCTION

&

ALTERNATING CURRENT

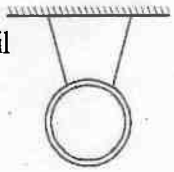
OUESTION FOR SHORT ANSWER

Q.1 Are induced emfs and currents different in any way from emfs and currents provided by a battery connected to a conducting loop?

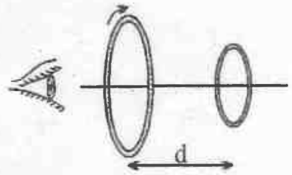
Q.2 Can a charged particle at rest be set in motion by the action of a magnetic field? If not, why not? If so, how? Consider both static and time-varying fields.

Q.3 In Faraday's law of induction, does the induced emf depend on the resistance of the circuit? If so, how?

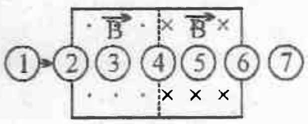
Q.4 Figure shows a copper ring that is hung from a ceiling by two threads. Describe in detail how you might most effectively use a bar magnet to get this ring to swing back and forth.



Q.5 Two conducting loops face each other a distance d apart, as shown in figure. An observer sights along their common axis from left to right. A clockwise current i is suddenly established in the larger loop by a battery not shown. (a) What is the direction of the induced current in the smaller loop? (b) What is the direction of the force (if any) that acts on the smaller loop?



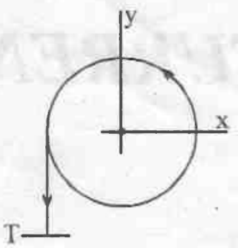
Q.6 A circular loop moves with constant velocity through regions where uniform magnetic fields of the same magnitude are directed into or out of the plane of the page, as indicated in figure. At which of the seven indicated positions will the induced current be (a) clockwise, (b) counterclockwise, and (c) zero?



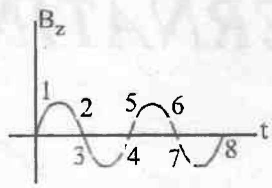
Q.7 Can an induced current ever establish a magnetic field $\vec{B}$ that is in the same direction as the magnetic field inducing the current? Justify your answer.

Q.8 A plane closed loop is placed in a uniform magnetic field. In what ways can the loop be moved without inducing an emf? Consider motions both of translation and rotation.

Q.9 Figure (a) shows a top view of the electron orbit in a betatron. Electrons are accelerated in a circular orbit in the xy plane and then withdrawn to strike the target T. The magnetic field $\vec{B}$ is along the z axis (the positive z axis is out of the page). The magnetic field B_z along this axis varies sinusoidally as shown in figure (b). Recall that the magnetic field must (i) guide the electrons in their circular path and (ii) generate the electric field that accelerates the electrons. Which quarter cycle(s) in figure are suitable (a) according to (i), (b) according to (ii), and (c) for operation of the betatron?



(a)



(b)

Q.10

(i) A piece of metal and a piece of non-metallic stone are dropped from the same height near the surface of the earth. Which one will reach the ground earlier?

(ii) A metallic loop is placed in a nonuniform magnetic field. will an emf be induced in the loop ?

(iii) A wire loop is held with its plane horizontal. A magnet with its north pole downward is allowed to fall through it from some height. Will the magnet fall with constant acceleration? What will happen if the poles are reversed?

(iv) A magnet is dropped down into long vertically copper tube . Show that, even neglecting air resistance the magnet will reach a constant terminal velocity .

(v) A magnet is dropped from the ceiling along the axis of a copper loop lying flat on the floor. If the falling magnet is photographed with a time sequence camera, what differences, if any will be noted if,
(i) the loop is at room temperature (ii) the loop is packed in dry ice ?

Q.11 A copper ring is suspended in a vertical plane by a thread. A steel bar is passed through the ring in the horizontal direction which is perpendicular to the plane of the loop. Then a magnet is similarly passed through the loop. Will the motion of the magnet and the bar affect the position of the ring?

Q.12 If the magnetic field outside a copper box is suddenly changed, what happens to the magnetic field inside the box ? Such low-resistivity metals are used to form enclosures which shield objects inside them against varying magnetic fields.

Q.13 Metallic (nonferromagnetic) and nonmetallic particles in a solid waste may be separated as follows. The waste is allowed to slide down an incline over permanent magnets. The metallic particles slow down as compared to the nonmetallic ones and hence are separated. Discuss the role of eddy currents in the process.

Q.14 A jet plane is flying due north . A potential difference is produced between he wing tips of the plane. Will a passenger sitting inside the plane also expect some emf between the wing tips? Will a tiny bulb connected to the wing tips glow?

Q.15 Is the inductance per unit length for a solenoid near its centre ;
(a) the same as (b) less than or (c) greater than
the inductance per unit length near its ends ?

Q.16 Two solenoids A & B have the same diameter & length & contain only one layer of windings, with adjacent turns touching, insulation thickness being negligible . Solenoid A contains many turns of fine wire & solenoid B contains fewer turns of heavier wire.
(i) which solenoid has the larger inductance ?
(i) which solenoid has the larger inductive time constant ? (material is same)

Q.17 If the flux passing through each turn of a coil is the same, the inductance of the coil may be computed from $L = \frac{N\phi_B}{i}$. How might one compute L for a coil for which this assumption is not valid .

Q.18 If a current in a source of emf is in the direction of the emf, the energy of the source decreases, if a current is in a direction opposite to the emf (as in charging a battery), the energy of the source increases . Do these statements apply to the inductor .

Q.19 Does the time required for the current in particular LR circuit to build up to any given fraction of its equilibrium value depend on the value of the applied emf .

Q.20 A steady current is set up in a coil with a very large inductive time constant . When the current is interupted with a switch a heavy arc tends to appear at the switch blades . Explain? [Note : interrupting currents in highly inductive circuits can be dangerous]

Q.21 What is the advantage of placing the two electric wires carrying ac close together?

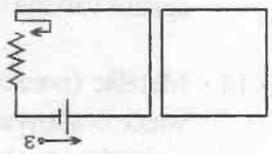
Q.22 In an LR series circuit the self induced emf is a maximum at the instant the switch is closed. How can this be since there is no current in the inductance at this instant .

Q.23 Explain what is meant by the statement "A motor acts as a motor and generator at the same time." Can the same be said for a generator?

Q.24 In a toroid, is the energy density larger near the inner radius or near the outer radius ?

Q.25 Two circular loops are placed with their centres separated by a fixed distance. How would you orient the loops to have (a) the largest mutual inductance (b) the smallest mutual inductance ?

Q.26 If the resistance R in the left hand circuit of figure is increased, what is the direction of the induced current in the right hand circuit ?



ONLY ONE OPTION IS CORRECT.

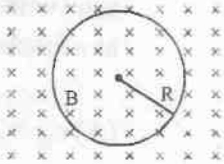
Take approx. 2 minutes for answering each question.

Q.1 An electron is moving in a circular orbit of radius R with an angular acceleration α. At the centre of the orbit is kept a conducting loop of radius r, (r <<R). The e.m.f induced in the smaller loop due to the motion of the electron is

(A) zero, since charge on electron in constant (B) $\frac{\mu_0 er^2}{4R}\alpha$

(C) $\frac{\mu_0 er^2}{4\pi R}\alpha$ (D) none of these

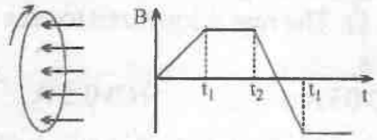
Q.2 a conducting loop of radius R is present in a uniform magnetic field B perpendicular the plane of the ring. If radius R varies as a function of time 't', as $R = R_0 + t$. The e.m.f induced in the loop is

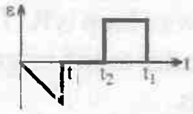
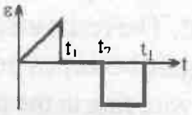
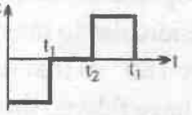
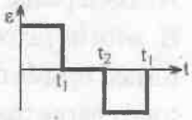


(A) $2\pi(R_0 + t)B$ clockwise (B) $\pi(R_0 + t)B$ clockwise

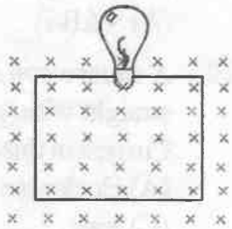
(C) $2\pi(R_0 + t)B$ anticlockwise (D) zero

Q.3 A wire loop is placed in a region of time varying magnetic field which is oriented orthogonally to the plane of the loop as shown in the figure. The graph shows the magnetic field variation as the function of time. Assume the positive emf is the one which drives a current in the clockwise direction and seen by the observer in the direction of B. Which of the following graphs best represents the induced emf as a function of time.



(A)  (B)  (C)  (D) 

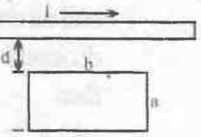
Q.4 A square wire loop of 10.0 cm side lies at right angles to a uniform magnetic field of 20T. A 10 V light bulb is in a series with the loop as shown in the fig. The magnetic field is decreasing steadily to zero over a time interval Δt. The bulb will shine with full brightness if Δt is equal to



(A) 20 ms (B) 0.02 ms

(C) 2 ms (D) 0.2 ms

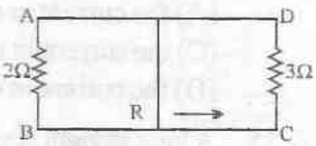
Q.5 A long straight wire is parallel to one edge as in fig. If the current in the long wire is varies in time as $I = I_0 e^{-t/\tau}$, what will be the induced emf in the loop?



(A) $\frac{\mu_0 bI}{\pi\tau} ln\left(\frac{d+a}{d}\right)$ (B) $\frac{\mu_0 bI}{2\pi\tau} ln\left(\frac{d+a}{d}\right)$

(C) $\frac{2\mu_0 bI}{\pi\tau} ln\left(\frac{d+a}{a}\right)$ (D) $\frac{\mu_0 bI}{\pi\tau} ln\left(\frac{d}{d+a}\right)$

Q.6 A rectangular loop with a sliding connector of length 10 cm is situated in uniform magnetic field perpendicular to plane of loop. The magnetic induction is 0.1 tesla and resistance of connector (R) is 1 ohm. The sides AB and CD have resistances 2 ohm and 3 ohm respectively. Find the current in the connector during its motion with constant velocity one metre/sec.



(A) $\frac{1}{110}$ A (B) $\frac{1}{220}$ A (C) $\frac{1}{55}$ A (D) $\frac{1}{440}$ A

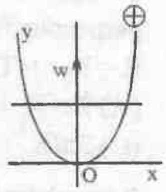
Q.7 The magnetic flux through a stationary loop with resistance R varies during interval of time T as $\phi = at(T-t)$. The heat generated during this time neglecting the inductance of loop will be

(A) $\frac{a^2T^3}{3R}$ (B) $\frac{a^2T^2}{3R}$ (C) $\frac{a^2T}{3R}$ (D) $\frac{a^2T^3}{R}$

Q.8 The dimensions of permeability of free space can be given by

(A) $[MLT^{-2}A^{-2}]$ (B) $[MLA^{-2}]$ (C) $[ML^{-3}T^2A^2]$ (D) $[MLA^{-1}]$

Q.9 A wire as a parabola $y = ax^2$ is located in a uniform magnetic field of inductance B, the vector B being perpendicular to the plane xy. At the moment t = 0 a connector starts translation wise from the parabola apex with a constant acceleration ω to find the emf of electromagnetic induction in the loop this formed as a function of y



(A) $\varepsilon_{in} = 2By\sqrt{\frac{2\omega}{a}}$ (B) $\varepsilon_{in} = By\sqrt{\frac{2\omega}{a}}$

(C) $\varepsilon_{in} = \frac{By}{2}\sqrt{\frac{2\omega}{a}}$ (D) $\varepsilon_{in} = \frac{By}{2}\sqrt{\frac{\omega}{a}}$

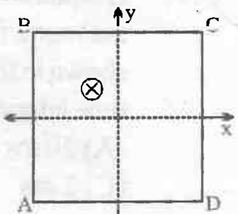
Q.10 A thin circular ring of area 10^{-2} m^2 is held perpendicular to a uniform magnetic field of induction 0.1 T. A small cut is made in the ring and the galvanometer is connected across the ends such that the total resistance of the circuit is 0.1 Ω. The ring is squeezed to area 0.5×10^{-2} m^2 in time 0.1 sec. The average induced current in the circuit is

(A) insufficient data (B) 0.05 A (C) 0.5 A (D) 5 A

Q.11 A closed planar wire loop of area A and arbitrary shape is placed in a uniform magnetic field of magnitude B, with its plane perpendicular to magnetic field. The resistance of the wire loop is R. The loop is now turned upside down by 180° so that its plane again becomes perpendicular to the magnetic field. The total charge that must have flowed through the wire ring in the process is

(A) < AB/R (B) = AB/R (C) = 2AB/R (D) None

Q.12 A square coil ABCD is placed in x-y plane with its centre at origin. A long straight wire, passing through origin, carries a current in negative z-direction. Current in this wire increases with time. The induced current in the coil is :



(A) clockwise (B) anticlockwise

(C) zero (D) alternating

Q.13 A vertical bar magnet is dropped from position on the axis of a fixed metallic coil as shown in fig - I. In fig - II the magnet is fixed and horizontal coil is dropped. The acceleration of the magnet and coil are a_1 and a_2 respectively then

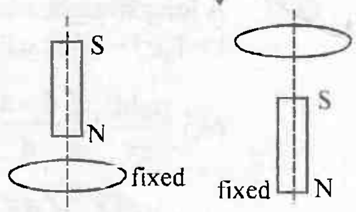


fig - I fig-II

(A) $a_1 > g$, $a_2 > g$ (B) $a_1 > g$, $a_2 < g$

(C) $a_1 < g$, $a_2 < g$ (D) $a_1 < g$, $a_2 > g$

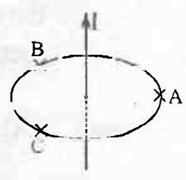
Q.14 Two identical coaxial circular loops carry a current *i* each circulating in the same direction. If the loops approach each other

(A) the current in each will decrease (B) the current in each will increase

(C) the current in each will remain the same

(D) the current in one will increase and in other will decrease

Q.15 A long straight conductor is placed along axis of a circular coil of radius R. If the current, as shown in figure, starts decreasing with time, the current induced in loop would be

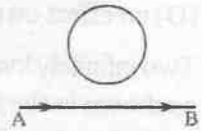


(A) clockwise (ACB) (B) anticlockwise (ABC)

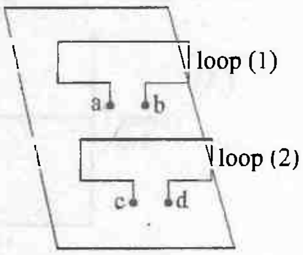
(C) can not be decided (D) there will be no induced current.

Q.16 In a long hollow vertical metal pipe a magnet is dropped. During its fall, the acceleration of magnet:
(A) will decrease linearly
(B) will decrease upto a value which is less than g.
(C) will decrease to zero and will attain a terminal speed
(D) may increase or decrease

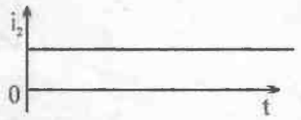
Q.17 In the arrangement shown in given figure current from A to B is increasing in magnitude. Induced current in the loop will
(A) have clockwise direction
(B) have anticlockwise direction
(C) be zero
(D) oscillate between clockwise and anticlockwise



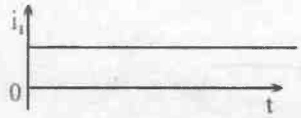
Q.18 An electric current i_1 can flow either direction through loop (1) and induced current i_2 in loop (2). Positive i_1 is when current is from 'a' to 'b' in loop (1) and positive i_2 is when the current is from 'c' to 'd' in loop (2)

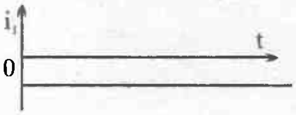


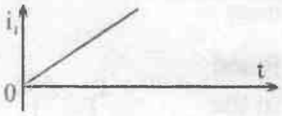
In an experiment, the graph of i_2 against time 't' is as shown below



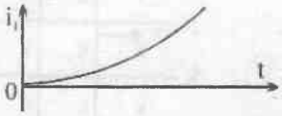
Which one(s) of the following graphs could have caused i_2 to behave as give above.

(A) 

(B) 

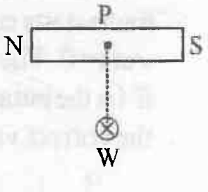
(C) 

(D) 

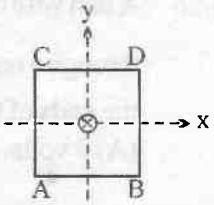
(E) 

Q.19 A bar magnet is released from rest along the axis of a very long, vertical copper tube after some time, the magnet
(A) will stop the tube
(B) will move with almost constant speed
(C) will move with acceleration g
(D) will oscillate

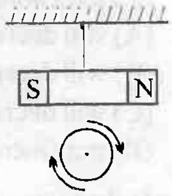
Q.20 Figure shows a bar magnet and a long straight wire W, carrying current into the plane of paper. Point P is the point of intersection of axis of magnet and the line of shortest distance between magnet and the wire. If P is the midpoint of the magnet, then which of the following statements is correct ?
(A) magnet experiences a torque in clockwise direction
(B) magnet experiences a torque in anticlockwise direction
(C) magnet experiences a force, normal to the line of shortest distance
(D) magnet experiences a force along the line of shortest distance



Q.21 A square coil ABCD is lying in xy plane with its centre at origin. A lng straight wire passing through origin carries a current $i = 2t$ in negative z-direction. The induced current in the coil is
(A) clockwise
(B) anticlockwise
(C) alternating
(D) zero

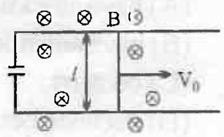


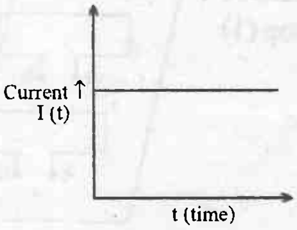
Q.22 A negative charge is given to a nonconducting loop and the loop is rotated in the plane of paper about its centre as shown in figure. The magnetic field produced by the ring affects a small magnet placed above the ring in the same plane:

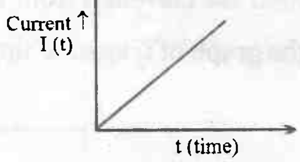


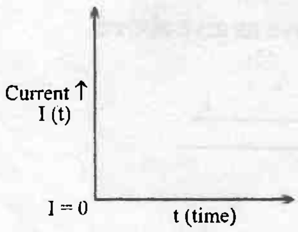
(A) the magnet does not rotate
(B) the magnet rotates clockwise as seen from below.
(C) the magnet rotates anticlockwise as seen from below
(D) no effect on magnet is there.

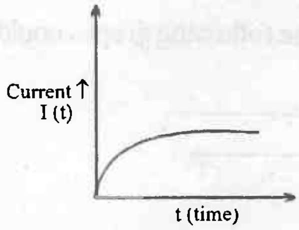
Q.23 Two infinitely long conducting parallel rails are connected through a capacitor C as shown in the figure. A conductor of length l is moved with constant speed v_0. Which of the following graph truly depicts the variation of current through the conductor with time?



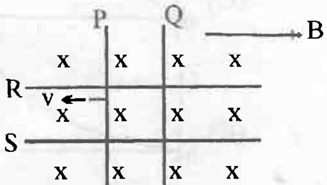
(A)


(B)


(C)


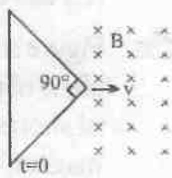
(D)


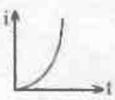
Q.24 Two identical conductors P and Q are placed on two frictionless rails R and S in a uniform magnetic field directed into the plane. If P is moved in the direction shown in figure with a constant speed then rod Q

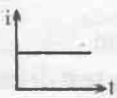


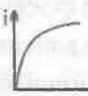
(A) will be attracted towards P
(B) will be repelled away from P
(C) will remain stationary
(D) may be repelled or attracted towards P

Q.25 The figure shows an isosceles triangle wire frame with apex angle equal to $\pi/2$. The frame starts entering into the region of uniform magnetic field B with constant velocity v at t= 0. The longest side of the frame is perpendicular to the direction of velocity. If i is the instantaneous current through the frame then choose the alternative showing the correct variation of i with time.



(A)


(B)


(C)


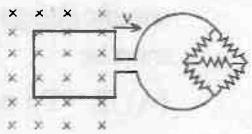
(D)


Q.26 A thin wire of length 2m is perpendicular to the xy plane. It is moved with velocity $\vec{v} = (2\hat{i} + 3\hat{j} + \hat{k})$ m/s through a region of magnetic induction $\vec{B} = (\hat{i} + 2\hat{j})$ Wb/m^2. Then potential difference induced between the ends of the wire :

(A) 2 volts (B) 4 volts (C) 0 volts (D) none of these

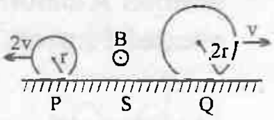
Q.27 A long metal bar of 30 cm length is aligned along a north south line and moves eastward at a speed of 10 ms^{-1}. A uniform magnetic field of 4.0 T points vertically downwards. If the south end of the bar has a potential of 0 V, the induced potential at the north end of the bar is
(A) + 12 V (B) – 12 V
(C) 0 V (D) cannot be determined since there is not closed circuit

Q.28 A square metal loop of side 10 cm and resistance 1 Ω is moved with a constant velocity partly inside a magnetic field of 2 Wbm^{-2}, directed into the paper, as shown in the figure. This loop is connected to a network of five resistors each of value 3 Ω. If a steady current of 1 mA flows in the loop, then the speed of the loop is



(A) 0.5 cms^{-1} (B) 1 cms^{-1} (C) 2 cms^{-1} (D) 4 cms^{-1}

Q.29 Two conducting rings P and Q of radii r and 2r rotate uniformly in opposite directions with centre of mass velocities 2v and v respectively on a conducting surface S. There is a uniform magnetic field of magnitude B perpendicular to the plane of the rings. The potential difference between the highest points of the two rings is



(A) zero (B) 4 Bvr
(C) 8 Bvr (D) 16 Bvr

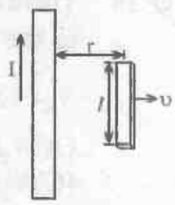
Q.30 Two coils, X and Y, are linked such that emf E is induced in Y when the current in X is changing at the rate $\left(\dot{I} = \frac{dI}{dt}\right)$. If a current I_0 is now made to flow through Y, the flux linked with X will be

(A) $EI_0\dot{I}$ (B) $\left(\frac{E}{\dot{I}}\right)I_0$ (C) $(E\dot{I})I_0$ (D) $\frac{I_0\dot{I}}{E}$

Q.31 A conductor AB of length l oriented along x-axis moves in XY plane with velocity $\vec{v} = v_0(\hat{i} - \hat{j})$. A magnetic field $\vec{B} = B_0(\hat{i} + \hat{j})$ exists in the region. The induced emf is

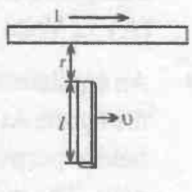
(A) $\sqrt{2}\,B_0 l v_0$ (B) $2B_0 l v_0$ (C) $B_0 l v_0$ (D) zero

Q.32 A conducting rod moves with constant velocity υ perpendicular to the long, straight wire carrying a current I as shown compute that the emf generated between the ends of the rod.



(A) $\frac{\mu_0 \upsilon I l}{\pi r}$ (B) $\frac{\mu_0 \upsilon I l}{2\pi r}$ (C) $\frac{2\mu_0 \upsilon I l}{\pi r}$ (D) $\frac{\mu_0 \upsilon I l}{4\pi r}$

Q.33 A conducting rod of length l moves with velocity υ a direction parallel to a long wire carrying a steady current I. The axis of the rod is maintained perpendicular to the wire with near end a distance r away as shown in the fig. Find the emf induced in the rod.



(A) $\frac{\mu_0 I \upsilon}{\pi} ln\left(\frac{r+l}{r}\right)$ (B) $\frac{2\mu_0 I \upsilon}{\pi} ln\left(\frac{r+l}{r}\right)$

(C) $\frac{\mu_0 I \upsilon}{\pi} ln\left(\frac{l}{r+l}\right)$ (D) $\frac{\mu_0 I \upsilon}{2\pi} ln\left(\frac{r+l}{r}\right)$

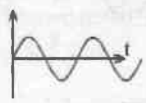
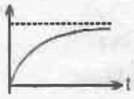
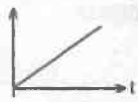
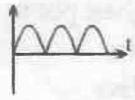
Q.34 A square loop of side a and resistance R is moved in the region of uniform magnetic field B(loop remaining completely insidefield) ,with a velocity v through a distance x . The work done is :

(A) $\frac{B\ell^2vx}{R}$ (B) $\frac{2B^2\ell^2vx}{R}$ (C) $\frac{4B^2\ell^2vx}{R}$ (D) none

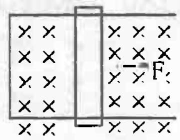
Q.35 A metallic rod of length L and mass M is moving under the action of two unequal forces F_1 and F_2 (directed opposite to each other) acting at its ends along its length. Ignore gravity and any external magnetic field. If specific charge of electrons is (e/m), then the potential difference between the ends of the rod is steady state must be

(A) $|F_1 - F_2|mL/eM$ (B) $(F_1 - F_2)\,mL/eM$ (C) $[\,mL/eM\,]\,ln\,[F_1/F_2]$ (D) None

Q.36 Two parallel rigid wires are fixed at a distance 'd' apart, with each wire in a vertical position. The top ends of the two wires are connected through an ideal inductor of inductance L. A straight connector of mass M can slide freely up and down, maintaining electrical contact with the two wires, in a horizontal position. A uniform magnetic field exists perpendicular to the plane of the wires. If the connector is released from rest, the graph of its downward velocity with time is :

(A)  (B)  (C)  (D) 

Q.37 A rod closing the circuit shown in figure moves along a U shaped wire at a constant speed v under the action of the force F. The circuit is in a uniform magnetic field perpendicular to the plane. Calculate F if the rate of heat generation in the circuti is Q.

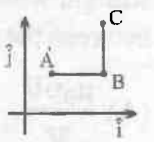


(A) F = Qv (B) $F = \frac{Q}{v}$ (C) $F = \frac{v}{Q}$ (D) $F = \sqrt{Qv}$

Q.38 Two parallel long straight conductors lie on a smooth surface. Two other parallel conductors rest on them at right angles so as to form a square of side a initially. A uniform magnetic field B exists at right angles to the plane containing the conductors. They start moving out with a constant velocity v. If r is the resistance per unit length of the wire the current in the circuit will be

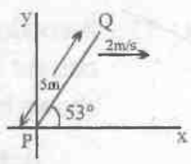
(A) $\frac{Bv}{r}$ (B) $\frac{Br}{v}$ (C) Bvr (D) Bv

Q.39 There is a uniform magnetic field B normal to the xy plane. A conductor ABC has length AB = l_1, parallel to the x-axis, and length BC = l_2, parallel to the y-axis. ABC moves in the xy plane with velocity $v_x\hat{i} + v_y\hat{j}$. The potential difference between A and C is proportional to



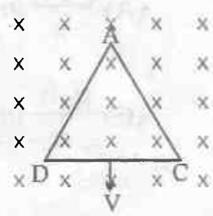
(A) $v_xl_1 + v_yl_2$ (B) $v_xl_2 + v_yl_1$
(C) $v_xl_2 - v_yl_1$ (D) $v_xl_1 - v_yl_2$

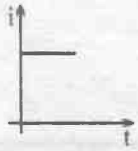
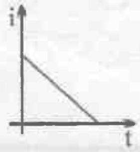
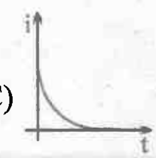
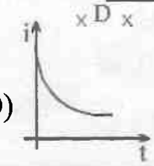
Q.40 A conducting rod PQ of length 5 m oriented as shown in figure is moving with velocity (2 m/s) $\hat{i}$ without any rotation in a uniform magnetic field $(3\hat{j} + 4\hat{k})$ Tesla. Emf induced in the rod is



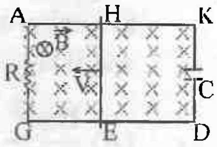
(A) 32 Volts (B) 40 Volt (C) 50 Volt (D) none

Q.41 An equilateral triangular loop ADC of some finite magnetic field $\vec{B}$ as shown in the figure. At time t = 0, side DC of loop is at edge of the magnetic field. Magnetic field is perpendicular to the paper inwards (or perpendicular to the plane of the coil). The induced current versus time graph will be as



(A)  (B)  (C)  (D) 

Q.42 In the circuit shown in figure, a conducting wire HE is moved with a constant speed V towards left. The complete circuit is placed in a uniform magnetic field $\vec{B}$ perpendicular to the plane of the circuit directed in inward direction. The current in HKDE is

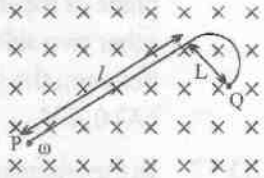


(A) clockwise
(B) anticlockwise
(C) alternating
(D) zero

Q.43 The magnetic field in a region is given by $\vec{B} = B_0\left(1+\frac{x}{a}\right)\hat{k}$. A square loop of edge - length d is placed with its edge along x & y axis. The loop is moved with constant velocity $\vec{V} = V_0\hat{i}$. The emf induced in the loop is

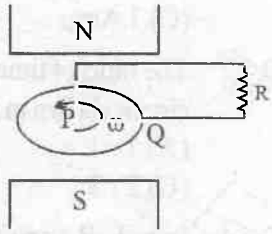
(A) $\frac{V_0B_0d^2}{a}$ (B) $\frac{V_0B_0d^2}{2a}$ (C) $\frac{V_0B_0a^2}{d}$ (D) None

Q.44 When a 'J' shaped conducting rod is rotating in its own plane with constant angular velocity w, about one of its end P, in a uniform magnetic field $\vec{B}$ directed normally into the plane of paper) then magnitude of emf induced across it will be



(A) $B\omega\sqrt{L^2+l^2}$
(B) $\frac{1}{2}B\omega L^2$
(C) $\frac{1}{2}B\omega(L^2+l^2)$
(D) $\frac{1}{2}B\omega l^2$

Q.45 A metal disc rotates freely, between the poles of a magnet in the direction indicated. Brushes P and Q make contact with the edge of the disc and the metal axle. What current, if any, flows through R?



(A) a current from P to Q
(B) a current from Q to P
(C) no current, because the emf in the disc is opposed by the back emf
(D) no current, because the emf induced in one side of the disc is opposed by the emf induced in the other side.
(E) no current, because no radial emf is induced in the disc

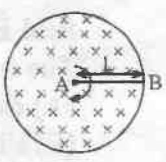
Q.46 For L-R circuit, the time constant is equal to
(A) twice the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
(B) ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
(C) half the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
(D) square of the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance

Q.47 A rectangular coil of single turn, having area A, rotates in a uniform magnetic field B an angular velocity ω about an axis perpendicular to the field. If initially the plane of coil is perpendicular to the field, then the average induced e.m.f. when it has rotated through 90° is

(A) $\frac{\omega BA}{\pi}$ (B) $\frac{\omega BA}{2\pi}$ (C) $\frac{\omega BA}{4\pi}$ (D) $\frac{2\omega BA}{\pi}$

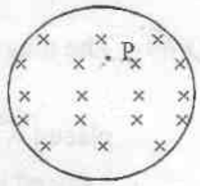
Q.48 A ring of resistance 10Ω, radius 10cm and 100 turns is rotated at a rate 100 revolutions per second about a fixed axis which is perpendicular to a uniform magnetic field of induction 10mT. The amplitude of the current in the loop will be nearly (Take : $\pi^2 = 10$)
(A) 200A (B) 2A (C) 0.002A (D) none of these

Q.49 A copper rod AB of length L, pivoted at one end A, rotates at constant angular velocity ω, at right angles to a uniform magnetic field of induction B. The e.m.f developed between the mid point C of the rod and end B is



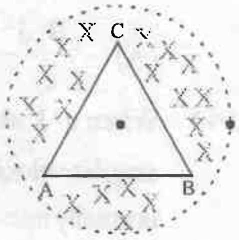
(A) $\frac{B\omega l^2}{4}$ (B) $\frac{B\omega l^2}{2}$ (C) $\frac{3B\omega l^2}{4}$ (D) $\frac{3B\omega l^2}{8}$

Q.50 Figure shows a uniform magnetic field B confined to a cylindrical volume and is increasing at a constant rate. The instantaneous acceleration experienced by an electron placed at P is



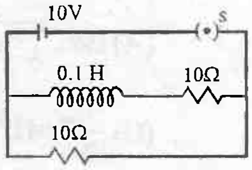
(A) zero (B) towards right
(C) towards left (D) upwards

Q.51 A triangular wire frame (each side = 2m) is placed in a region of time variant magnetic field having $dB/dt = \sqrt{3}$ T/s. The magnetic field is perpendicular to the plane of the triangle. The base of the triangle AB has a resistance 1 Ω while the other two sides have resistance 2Ω each. The magnitude of potential difference between the points A and B will be



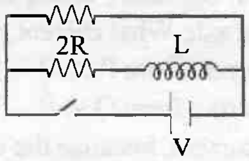
(A) 0.4 V (B) 0.6 V (C) 1.2 V (D) None

Q.52 In the adjoining circuit, initially the switch S is open. The switch 'S' is closed at t = 0. The difference between the maximum and minimum current that can flow in the circuit is



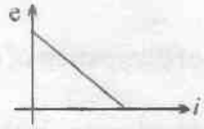
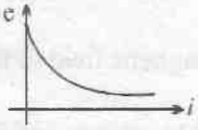
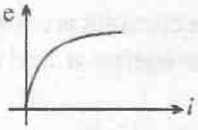
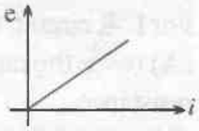
(A) 2 Amp (B) 3 Amp
(C) 1 Amp (D) nothing can be concluded

Q.53 The ratio of time constant in charging and discharging in the circuit shown in figure is



(A) 1 : 1 (B) 3 : 2
(C) 2 : 3 (D) 1 : 3

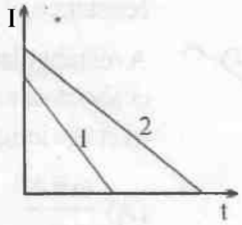
Q.54 In an L-R circuit connected to a battery of constant e.m.f. E switch S is closed at time t = 0. If e denotes the magnitude of induced e.m.f. across inductor and i the current in the circuite at any time t. Then which of the following graphs shows the variation of e with i ?

(A)  (B)  (C)  (D) 

Q.55 A curren of 2A is increasing at a rate of 4 A/s through a coil of inductance 2H. The energy stored in the inductor per unit time is

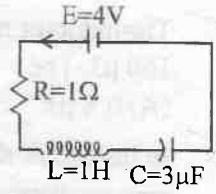
(A) 2 J/s (B) 1 J/s (C) 16 J/s (D) 4 J/s

Q.56 Two identical inductance carry currents that vary with time according to linear laws (as shown in figure). In which of two inductance is the self induction emf greater?



(A) 1
(B) 2
(C) same
(D) data are insufficient to decide

Q.57 The current in the given circuit is increasing with a rate a = 4 amp/s. The charge on the capacitor at an instant when the current in the circuit is 2 amp will be :



(A) 4μC (B) 5μC
(C) 6μC (D) none of these

Q.58 L, C and R represent physical quantities inductance, capacitance and resistance. The combination which has the dimensions of frequency is

(A) $\frac{1}{RC}$ and $\frac{R}{L}$ (B) $\frac{1}{\sqrt{RC}}$ and $\sqrt{\frac{R}{L}}$ (C) $\sqrt{LC}$ (D) $\frac{C}{L}$

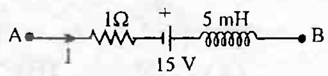
Q.59 A coil of inductance 5H is joined to a cell of emf 6V through a resistance 10Ω at time t = 0. The emf across the coil at time t = $ln\sqrt{2}$ s is:
(A) 3V (B) 1.5 V (C) 0.75 V (D) 4.5 V

Q.60 A long solenoid of N turns has a self inductance L and area of cross section A. When a current i flows through the solenoid, the magnetic field inside it has magnitude B. The current i is equal to:
(A) BAN/L (B) BANL (C) BN/AL (D) B/ANL

Q.61 A long straight wire of circular cross-section is made of a non-magnetic material. The wire is of radius a. The wire carries a current I which is uniformly ditributed over its cross-section. The energy stored per unit lenght in the magnetic field contained within the wire is

(A) $U = \frac{\mu_0 I^2}{8\pi}$ (B) $U = \frac{\mu_0 I^2}{16\pi}$ (C) $U = \frac{\mu_0 I^2}{4\pi}$ (D) $U = \frac{\mu_0 I^2}{2\pi}$

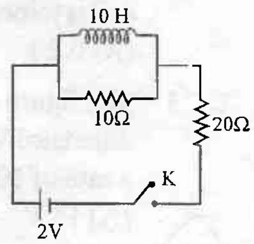
Q.62 The network shown in the figure is part of a complete circuit. If at a certain instant, the current I is 5A and it is decreasing at a rate of 10^3 As^{-1} then $V_B - V_A$ equals



(A) 20 V (B) 15 V (C) 10 V (D) 5 V

Q.63 In **Problem 62**, if I is reversed in direction, then $V_B - V_A$ equals
(A) 5 V (B) 10 V (C) 15 V (D) 20 V

Q.64 Two resistors of 10 Ω and 20 Ω and an ideal inductor of 10 H are connected to a 2 V battery as shown. The key K is inserted at time t = 0. The initial (t = 0) and final (t →∞) currents through battery are



(A) $\frac{1}{15}$ A, $\frac{1}{10}$ A (B) $\frac{1}{10}$ A, $\frac{1}{15}$ A

(C) $\frac{2}{15}$ A, $\frac{1}{10}$ A (D) $\frac{1}{15}$ A, $\frac{2}{25}$ A

Q.65 A small coil of radius r is placed at the centre of a large coil of radius R, where R >> r. The coils are coplanar. The coefficient inductance between the coils is

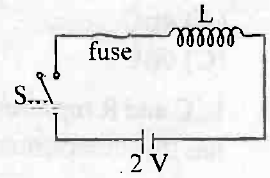
(A) $\frac{\mu_0 \pi r}{2R}$ (B) $\frac{\mu_0 \pi r^2}{2R}$ (C) $\frac{\mu_0 \pi r^2}{2R^2}$ (D) $\frac{\mu_0 \pi r}{2R^2}$

Q.66 Two long parallel wires whose centres are a distance d apart carry equal currents in opposite directions. If the flux within wires is neglected, the inductance of such arrangement of wire of length l and radius a will be

(A) $L = \frac{\mu_0 l}{\pi}\log_e\frac{d-a}{a}$ (B) $L = \frac{\mu_0 l}{\pi}\log_e\frac{d}{a}$ (C) $L = \frac{\mu_0 l}{\pi}\log_e\frac{a}{d}$ (D) none

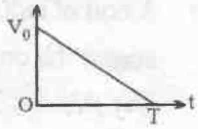
Q.67 The inductor in a L–C oscillation has a maximum potential difference of 16 V and maximum energy of 160 μJ. The value of capacitor in L–C circuit is
(A) 0.8 μF (B) 0.625 μF (C) 1.6 μF (D) 1.25 μF

Q.68 In the circuit shown, the cell is ideal. The coil has an inductance of 4H and zero resistance. F is a fuse of zero resistance and will blow when the current through it reaches 5A. The switch is closed at t = 0. The fuse will blow :



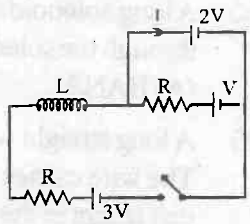
(A) just after t=0 (B) after 2s
(C) after 5s (D) after 10s

Q.69 A coil of inductance L and zero resistance is connected to a source of variable emf at t = 0. The emf of the source is varied with time according to the graph shown on the right above. What will be the average current that flows through the coil during time T?



(A) $V_0T/2L$ (B) $V_0T/3L$
(C) $3V_0T/2L$ (D) V_0T/L

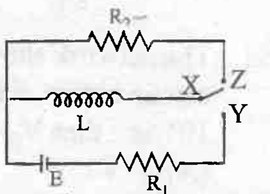
Q.70 In the LR circuit shown, what is the variation of the current I as a function of time? The switch is closed at time t = 0 sec.



(A) $\frac{V}{R}\left(1-e^{-\frac{Rt}{L}}\right)$ (B) $\frac{V}{R}e^{-\frac{Rt}{L}}$

(C) $-\frac{V}{R}e^{-\frac{Rt}{L}}$ (D) None

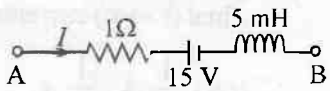
Q.71 In the circuit shown, X is joined to Y for a long time, and then X is joined to Z. The total heat produced in R_2 is :



(A) $\frac{LE^2}{2R_1^2}$ (B) $\frac{LE^2}{2R_2^2}$ (C) $\frac{LE^2}{2R_1R_2}$ (D) $\frac{LE^2R_2}{2R_1^2}$

Q.72 An induction coil stores 32 joules of magnetic energy and dissipates energy as heat at the rate of 320 watts. When a current of 4 amperes is passed through it. Find the time constant of the circuit when the coil is joined across a battery.
(A) 0.2 s (B) 0.1 s (C) 0.3 s (D) 0.4 s

Q.73 The figure shows a part of a complete circuit. The potential difference $V_B - V_A$ when the current I is 5A and is decreasing at a rate of 10^3 As^{-1} is given by

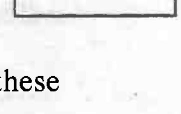


(A) 15 V (B) 10 V (C) –15 V (D) 20 V

Q.74 In a L–R decay circuit, the initial current at t = 0 is I. The total charge that has flown through the resistor till the energy in the inductor has reduced to one–fourth its initial value, is
(A) LI/R (B) LI/2R (C) $LI\sqrt{2}/R$ (D) None

Q.75 A capacitor of capacitance 2 μF is charged to a potential difference of 12 V. It is then connected across an inductor of inductance 0.6 mH. The current in the circuit when the potential difference across the capacitor is 6 V is :
(A) 3.6 A (B) 2.4 A (C) 1.2 A (D) 0.6 A

Q.76 In an LC circuit, the capacitor has maximum charge q_0. The value of $\left.\frac{di}{dt}\right|_{max}$ is

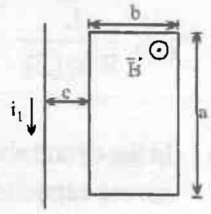


(A) $\frac{q_0}{LC}$ (B) $\frac{q_0}{\sqrt{LC}}$ (C) $\frac{q_0}{LC}-1$ (D) none of these

Q.77 An inductor coil stores U energy when i current is passed through it and dissipates energy at the rate of P. The time constant of the circuit, when this coil is connected across a battery of zero internal resistance is

(A) $\frac{4U}{P}$ (B) $\frac{U}{P}$ (C) $\frac{2U}{P}$ (D) $\frac{2P}{U}$

Q.78 The mutual inductance between the rectangular loop and the long straight wire as shown in figure is M.



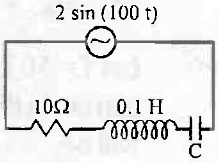
(A) M = Zero (B) $M = \frac{\mu_0 a}{2\pi} \ln\left(1 + \frac{c}{b}\right)$

(C) $M = \frac{\mu_0 b}{2\pi} \ln\left(\frac{a+c}{b}\right)$ (D) $M = \frac{\mu_0 a}{2\pi} \ln\left(1 + \frac{b}{c}\right)$

Q.79 A long straight wire is placed along the axis of a circular ring of radius R. The mutual inductance of this system is

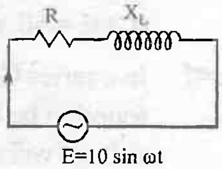
(A) $\frac{\mu_0 R}{2}$ (B) $\frac{\mu_0 \pi R}{2}$ (C) $\frac{\mu_0}{2}$ (D) 0

Q.80 The power factor of the circuit is $1/\sqrt{2}$. The capacitance of the circuit is equal to



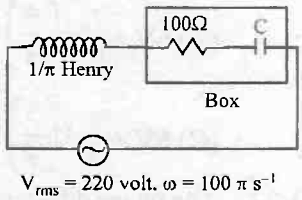
(A) 400 μF (B) 300 μF
(C) 500 μF (D) 200 μF

Q.81 An ac-circuit having supply voltage E consists of a resistor of resistance 3Ω and an inductor of reactance 4Ω as shown in the figure. The voltage across the inductor at t = T/2 is



(A) 2 volts (B) 10 volts
(C) zero (D) 4.8 volts

Q.82 In the circuit, as shown in the figure, if the value of R.M.S current is 2.2 ampere, the power factor of the box is



(A) $\frac{1}{\sqrt{2}}$ (B) 1

(C) $\frac{\sqrt{3}}{2}$ (D) $\frac{1}{2}$

Q.83 When 100 V DC is applied across a solenoid a current of 1 A flows in it. When 100 V AC is applied across the same coil, the current drops to 0.5 A. If the frequency of the AC source is 50 Hz, the impedance and inductance of the solenoid are:

(A) 100Ω, 0.93 H (B) 200Ω, 1.0 H (C) 10Ω, 0.86H (D) 200Ω, 0.55 H

Q.84 An inductive circuit contains resistance of 10 Ω and an inductance of 2.0 H. If an AC voltage of 120 V and frequency 60 Hz is applied to this circuit, the current would be nearly:

(A) 0.8 A (B) 0.48 A (C) 0.16 A (D) 0.32 A

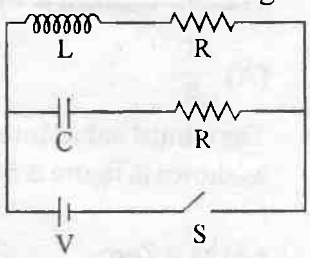
Q.85 The power in ac circuit is given by $P = E_{rms} I_{rms} \cos\phi$. The vale of cos ϕ in series LCR circuit at resonance is:

(A) zero (B) 1 (C) $\frac{1}{2}$ (D) $\frac{1}{\sqrt{2}}$

Q.86. In ac circuit when ac ammeter is connected it reads i current if a student uses dc ammeter in place of ac ammeter the reading in the dc ammeter will be:

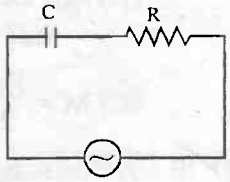
(A) $\frac{i}{\sqrt{2}}$ (B) $\sqrt{2}\,i$ (C) 0.637 i (D) zero

Q.87 In the circuti shown in the figure, $R = \sqrt{\frac{L}{C}}$. Switch S is closed at time t = 0. The current throughC and L would be equal after a time t equal to:



(A) CR
(B) CR ln (2)
(C) $\frac{L}{R\ln(2)}$
(D) LR

Q.88 In the circuit shown if the emf of source at an instant is 5 V, the potential difference across capacitor at the same instant is 4 V. The potential difference across R at that instant can be

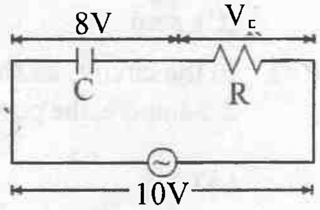


(A) 3V
(B) 9V
(C) $\frac{3}{\sqrt{2}}$ V.
(D) none

Q.89 An AC current is given by $I = I_0 + I_1$ sin wt then its rms value will be
(A) $\sqrt{I_0^2 + 0.5I_1^2}$
(B) $\sqrt{I_0^2 + 0.5I_0^2}$
(C) 0
(D) $I_0/\sqrt{2}$

Q.90 Let f = 50 Hz, and C = 100 μF in an AC circuit containing a capicator only. If the peak value of the current in the circuit is 1.57 A at t = 0. The expression for the instantaneous voltage across the capacitor will be
(A) $E = 50 \sin(100\pi t - \pi/2)$
(B) $E = 100 \sin(50\pi t)$
(C) $E = 50 \sin 100\pi t$
(D) $E = 50 \sin(100\pi t + \pi/2)$

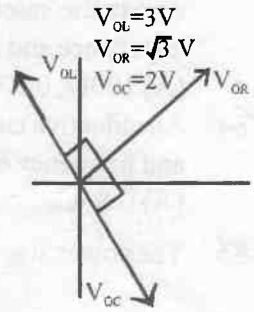
Q.91 In a series CR circuit shown in figure, the applied voltage is 10 V and the voltage across capacitor is found to be 8V. Then the voltage across R, and the phase difference between current and the applied voltage will respectively be



(A) 6V, $\tan^{-1}\left(\frac{4}{3}\right)$
(B) 3V, $\tan^{-1}\left(\frac{3}{4}\right)$
(C) 6V, $\tan^{-1}\left(\frac{5}{3}\right)$
(D) none

Q.92 The phase difference between current and voltage in an AC circuit is π/4 radian. If the frequency of AC is 50 Hz, then the phase difference is equivalent to the time difference :
(A) 0.78 s
(B) 15.7 ms
(C) 0.25 s
(D) 2.5 ms

Q.93 The given figure represents the phasor diagram of a series LCR circuit connected to an ac source. At the instant t' when the source voltage is given by $V = V_0\cos\omega t'$, the current in the circuit will be



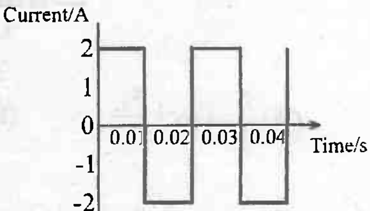
(A) $I = I_0 \cos(\omega t' + \pi/6)$
(B) $I = I_0 \cos(\omega t' - \pi/6)$
(C) $I = I_0 \cos(\omega t' + \pi/3)$
(D) $I = I_0 \cos(\omega t' - \pi/3)$

Q.94 A coil, a capacitor and an AC source of rms voltage 24 V are connected in series. By varying the frequency of the source, a maximum rms current of 6A is observed. If coil is connected to a battery of emf 12 volt and internal resistance 4Ω, then current through it in steady state is
(A) 2.4 A
(B) 1.8 A
(C) 1.5 A
(D) 1.2 A

Q.95 Power factor of an L-R series circuit is 0.6 and that of a C–R series circuit is 0.5. If the element (L, C, and R) of the two circuits are joined in series the power factor of this circuit is found to be 1. The ratio of the resistance in the L-R circuit to the resistance in the C–R circuit is

(A) 6/5 (B) 5/6 (C) $\frac{4}{3\sqrt{3}}$ (D) $\frac{3\sqrt{3}}{4}$

Q.96 The direct current which would give the same heating effect in an equal constant resistance as the current shown in figure, i.e. the r m.s. current, is



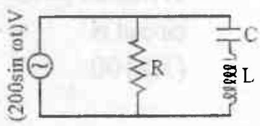
(A) zero (B) $\sqrt{2}$ A

(C) 2A (D) $2\sqrt{2}$ A

Q.97 The effective value of current $i = 2 \sin 100\pi t + 2 \sin(100\pi t + 30°)$ is :

(A) $\sqrt{2}$ A (B) $2\sqrt{2+\sqrt{3}}$ (C) 4 (D) None

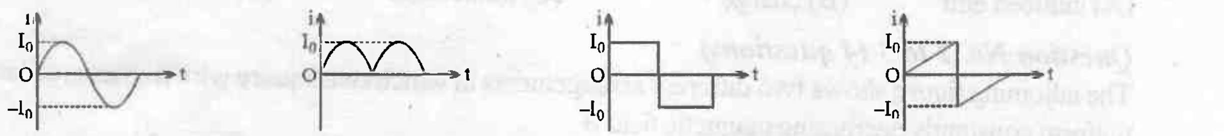
Q.98 In the circuit diagram shown, $X_C = 100\ \Omega$, $X_L = 200\ \Omega$ and $R = 100\ \Omega$. The effective current through the source is



(A) 2 A (B) $\sqrt{2}$ A

(C) 0.5 A (D) $2\sqrt{2}$ A

Q.99 If I_1, I_2, I_3 and I_4 are the respective r.m.s. values of the time varying currents as shown in the four cases I, II, III and IV Then identify the correct relations.

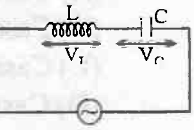


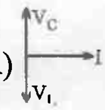
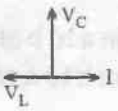
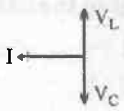
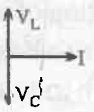
(A) $I_1 = I_2 = I_3 = I_4$ (B) $I_3 > I_1 = I_2 > I_4$ (C) $I_3 > I_4 > I_2 = I_1$ (D) $I_3 > I_2 > I_1 > I_4$

Q.100 In series LR circuit $X_L = 3R$. Now a capacitor with $X_C = R$ is added in series. Ratio of new to old power factor is

(A) 1 (B) 2 (C) $\frac{1}{\sqrt{2}}$ (D) $\sqrt{2}$

Q.101 The current I, potential difference V_L across the inductor and potential difference V_C across the capacitor in circuit as shown in the figure are best represented vectorially as

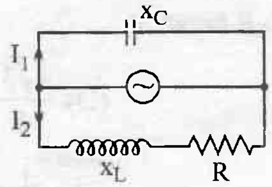


(A)  (B)  (C)  (D) 

Q.102 A coil, a capacitor and an A.C. source of rms voltage 24 V are connected in series. By varying the frequency of the source, a maximum rms current of 6 A is observed. If this coil is connected to a battery of emf 12 V and internal resistance 4Ω, the current through it will be

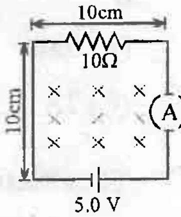
(A) 2.4 A (B) 1.8 A (C) 1.5 A (D) 1.2 A

Q.103 In the shown AC circuit phase different between currents I_1 and I_2 is



(A) $\frac{\pi}{2} - \tan^{-1}\frac{X_L}{R}$ (B) $\tan^{-1}\frac{X_L - X_C}{R}$ (C) $\frac{\pi}{2} + \tan^{-1}\frac{X_L}{R}$ (D) $\tan^{-1}\frac{X_L - X_C}{R} + \frac{\pi}{2}$

Q.104 The circuit shown is in a uniform magnetic field that is into the page and is decreasing in magnitude at the rate of 150 tesla/second. The ideal ammeter reads



(A) 0.15 A (B) 0.35 A (C) 0.50 A (D) 0.65 A

Q.105 A capacitor C = 2μF and an inductor with L = 10 H and coil resistance 5 Ω are in series in a circuit. When an alternating current of r.m.s. value 2A flows in the circuit, the average power in watts in the circuit is
(A) 100 (B) 50 (C) 20 (D) 10

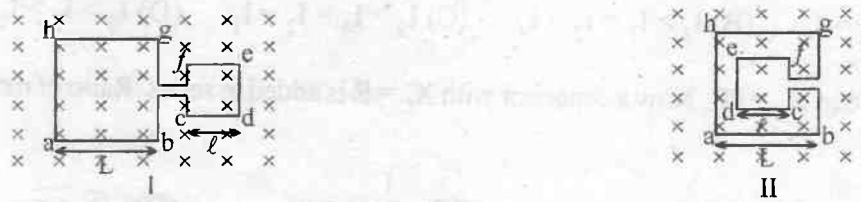
ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 The dimension of the ratio of magnetic flux and the resistance is equal to that of :
(A) induced emf (B) charge (C) inductance (D) current

Question No. 2 to 5 (4 questions)

The adjoining figure shows two different arrangements in which two square wire frames are placed in a uniform constantly decreasing magnetic field B.



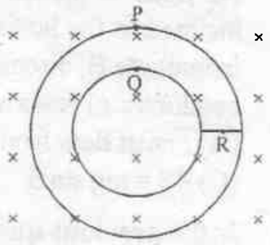
Q.2 The value of magnetic flux in each case is given by
(A) Case I: $\Phi = \pi(L^2 + \ell^2)B$; Case II: $\Phi = \pi(L^2 - \ell^2)B$
(B) Case I: $\Phi = \pi(L^2 + \ell^2)B$; Case II: $\Phi = \pi(L^2 + \ell^2)B$
(C) Case I: $\Phi = (L^2 + \ell^2)B$; Case II: $\Phi = (L^2 - \ell^2)B$
(D) Case I: $\Phi = (L + \ell)^2B$; Case II: $\Phi = \pi(L - \ell)^2B$

Q.3 The direction of induced current in the case I is
(A) from a to b and from c to d (B) from a to b and from f to e
(C) from b to a and from d to c (D) from b to a and from e to f

Q.4 The direction of induced current in the case II is
(A) from a to b and from c to d (B) from b to a and from f to e
(C) from b to a and from c to d (D) from a to b and from d to c

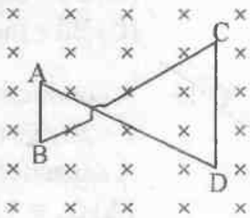
Q.5 If I_1 and I_2 are the magnitudes of induced current in the cases I and II, respectively, then
(A) $I_1 = I_2$ (B) $I_1 > I_2$ (C) $I_1 < I_2$ (D) nothing can be said

Q.6 Figure shown plane figure made of a conductor located in a magnetic field along the inward normal to the plane of the figure. The magnetic field starts diminishing. Then the induced current



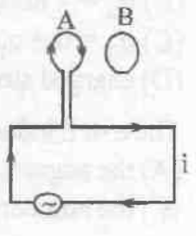
(A) at point P is clockwise
(B) at point Q is anticlockwise
(C) at point Q is clockwise
(D) at point R is zero

Q.7 A conducting wire frame is placed in a magnetic field which is directed into the paper. The magnetic field is increasing at a constant rate. The directions of induced currents in wires AB and CD are



(A) B to A and D to C
(B) A to B and C to D
(C) A to B and D to C
(D) B to A and C to D

Q.8 Two circular coils A and B are facing each other as shown in figure. The current i through A can be altered



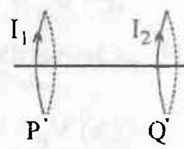
(A) there will be repulsion between A and B if i is increased
(B) there will be attraction between A and B if i is increased
(C) there will be neither attraction nor repulsion when i is changed
(D) attraction or repulsion between A and B depends on the direction of current. It does not depend whether the current is increased or decreased.

Q.9 When a magnet with its magnetic moment along the axis of a circular coil and directed towards the coil is withdrawn away from the coil, parallel to itself, the current in the coil, as seen by the withdrawing magnet is
(A) zero
(B) clockwise
(C) anticlockwise
(D) independent of the resistance of the coil

Q.10 A bar magnet is moved along the axis of copper ring placed far away from the magnet. Looking from the side of the magnet, an anticlockwise current is found to be induced in the ring. Which of the following may be true?
(A) The south pole faces the ring and the magnet moves towards it.
(B) The north pole faces the ring and the magnet moves towards it.
(C) The south pole faces the ring and the magnet moves away from it.
(D) The north pole faces the ring and the magnet moves away from it.

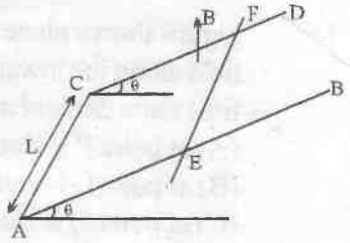
Q.11 In previous question, if P is on the left of midpoint :
(A) magnet experiences no torque
(B) magnet experiences no net force but experiences a torque
(C) magnet experiences a rightward force as well as a torque
(D) magnet will not experiences a rightward force as well as a torque

Q.12 Two circular coils P & Q are fixed coaxially & carry currents I_1 and I_2 respectively



(A) if $I_2 = 0$ & P moves towards Q, a current in the samedirection as I_1 is induced in Q
(B) if $I_1 = 0$ & Q moves towards P, a current in the opposite direction to that of I_2 isinduced in P.
(C) when $I_1 \neq 0$ and $I_2 \neq 0$ are in the same direction then the two coils tend to move apart.
(D) when $I_1 \neq 0$ and $I_2 \neq 0$ are in opposite directions then the coils tends to move apart.

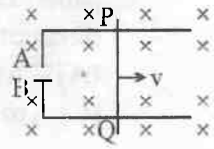
Q.13 AB and CD are smooth parallel rails, separated by a distance l, and inclined to the horizontal at an angle θ. A uniform magnetic field of magnitude B, directed vertically upwards, exists in the region. EF is a conductor of mass m, carrying a current i. For EF to be in equilibrium,



(A) i must flow from E to F (B) $Bil = mg \tan\theta$
(C) $Bil = mg \sin\theta$ (D) $Bil = mg$

Q.14 In the **previous question**, if B is normal to the plane of the rails
(A) $Bil = mg \tan\theta$ (B) $Bil = mg \sin\theta$
(C) $Bil = mg \cos\theta$ (D) equilibrium cannot be reached

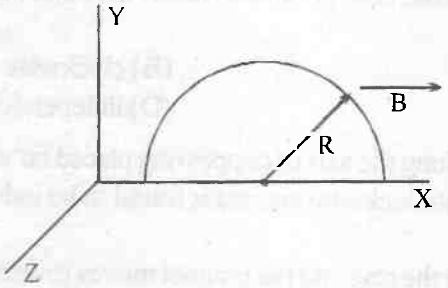
Q.15 A conducting rod PQ of length L = 1.0 m is moving with a uniform speed v = 20 m/s in a uniform magnetic field B = 4.0 T directed into the paper. A capacitor of capacity C = 10 μF is connected as shown in figure. Then



(A) $q_A = +800\mu C$ and $q_B = -800\mu C$
(B) $q_A = -800\mu C$ and $q_B = +800\mu C$
(C) $q_A = 0 = q_B$
(D) charged stored in the capacitor increases exponentially with time

Q.16 The e.m.f. induced in a coil of wire, which is rotating in a magnetic field, does not depend on
(A) the angular speed of rotation (B) the area of the coil
(C) the number of turns on the coil (D) the resistance of the coil

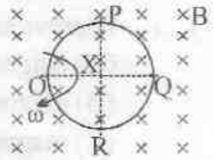
Q.17 A semicircle conducting ring of radius R is placed in the xy plane, as shown in the figure. A uniform magnetic field is set up along the x–axis. No emf, will be induced in the ring. if



(A) it moves along the x–axis (B) it moves along the y–axis
(C) it moves along the z-axis (D) it remains stationary

Question No. 18 to 20 (3 questions)

A conducting ring of radius a is rotated about a point O on its periphery as shown in the figure in a plane perpendicular to uniform magnetic field B which exists everywhere. The rotational velocity is ω.

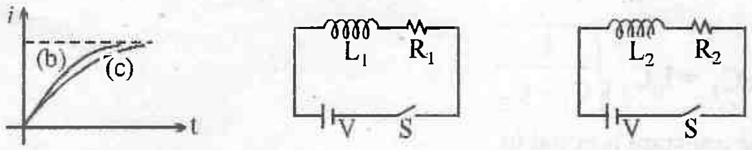


Q.18 Choose the correct statement(s) related to the potential of the points P, Q and R
(A) $V_P - V_O > 0$ and $V_R - V_O < 0$ (B) $V_P = V_R > V_O$
(C) $V_O > V_P = V_Q$ (D) $V_Q - V_P = V_P - V_O$

Q.19 Choose the correct statement(s) related to the magnitude of potential differences
(A) $V_P - V_O = \frac{1}{2} B\omega a^2$ (B) $V_P - V_Q = \frac{1}{2} B\omega a^2$
(C) $V_Q - V_O = 2B\omega a^2$ (D) $V_P - V_R = 2B\omega a^2$

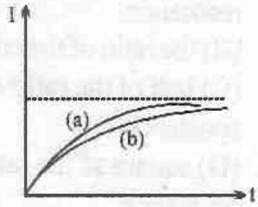
Q.20 Choose the correct statement(s) related to the induced current in the ring
(A) Current flows from Q $\longrightarrow$ P $\longrightarrow$ O $\longrightarrow$ R $\longrightarrow$ Q
(B) Current flows from Q $\longrightarrow$ R $\longrightarrow$ O $\longrightarrow$ P $\longrightarrow$ Q
(C) Current flows from Q $\longrightarrow$ P $\longrightarrow$ O and from Q $\longrightarrow$ R $\longrightarrow$ O
(D) No current flows

Q.21 Current growth in two L-R circuits (b) and (c) as shown in figure (a). Let L_1, L_2, R_1 and R_2 be the corresponding values in two circuits. Then
(A) $R_1 > R_2$ (B) $R_1 = R_2$ (C) $L_1 > L_2$ (D) $L_1 < L_2$



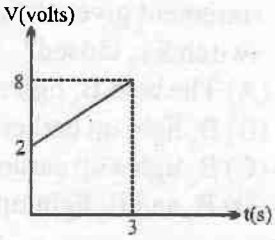
(a) (b) (c)

Q.22 A circuit consisting of a constant e.m.f. 'E', a self induction 'L' and a resistance 'R' is closed at t = 0. The relation between the current I in the circuit and time t is as shown by curve 'a' in the fig. When one or more of parameters E, R & L are changed, the curve 'b' is obtained. The steady state current is same in both the cases. Then it is possible that :



(A) E & R are kept constant & L is increased
(B) E & R are kept constant & L is decreased
(C) E & R are both halved and L is kept constant
(D) E & L are kept constant and R is decreased

Q.23 A circuit element is placed in a closed box. At time t=0, constant current generator supplying a current of 1 amp, is connected across the box. Potential difference across the box varies according to graph shown in figure. The element in the box is :



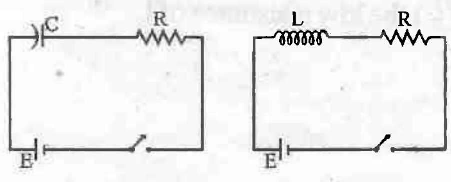
(A) resistance of 2Ω (B) battery of emf 6V
(C) inductance of 2H (D) capacitance of 0.5F

Q.24 A constant current i is maintained in a solenoid. Which of the following quantities will increase if an iron rod is inserted in the solenoid along its axis?
(A) magnetic field at the centre. (B) magnetic flux linked with the solenoid
(C) self-inductance of the solenoid (D) rate of Joule heating.

Q.25 The symbols L, C, R represent inductance, capacitance and resistance respectively. Dimension of frequency are given by the combination
(A) 1 / RC (B) R / L (C) $\frac{1}{\sqrt{LC}}$ (D) C / L

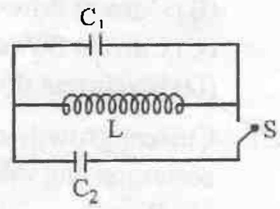
Q.26 An LR circuit with a battery is connected at t = 0. Which of the following quantities is not zero just after the circuit
(A) current in the circuit (B) magnetic field energy in the inductor
(C) power delivered by the battery (D) emf induced in the inductor

Q.27 The switches in figures (a) and (b) are closed at t = 0
(A) The charge on C just after t = 0 is EC.
(B) The charge on C long after t = 0 is EC.
(C) The current in L just after t = 0 is E/R.
(D) The current in L long after t = 0 is E/R.



(a) (b)

Q.28 At a moment (t = 0) when charge on capacitor C_1 is zero, the switch is closed. If I_0 be the current through inductor at that instant, for t > 0,



(A) maximum current through inductor equals $I_0/2$.

(B) maximum current through inductor equals $\frac{C_1 I_0}{C_1 + C_2}$

(C) maximum charge on $C_1 = \frac{C_1 I_0 \sqrt{LC_1}}{C_1 + C_2}$

(D) maximum charge on $C_1 = I_0 C_1 \sqrt{\frac{L}{C_1 + C_2}}$

Q.29 For L – R circuit, the time constant is equal to

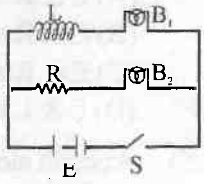
(A) twice the ratio of the energy stored in the magnetic field to the rate of the dissipation of energy in the resistance.

(B) the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance.

(C) half of the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance.

(D) square of the ratio of the energy stored in the magnetic field to the rate of dissipation energy in the resistance.

Q.30 An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch S as shown in the figure. The resistance of coil having inductance L is also R. Which of the following statement gives the correct description of the happenings when the switch S is closed?



(A) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright.

(B) B_1 light up earlier and finally both the bulbs acquire equal brightness.

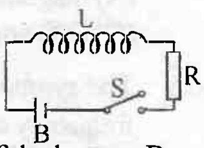
(C) B_2 lights up earlier and finally B_1 shines brighter than B_2.

(D) B_1 and B_2 light up together with equal brightness all the time.

Q.31 Which of the following quantities can be written in SI units in $Kgm^2A^{-2}S^{-3}$?

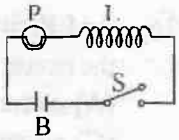
(A) Resistance (B) Inductance (C) Capacitance (D) Magnetic flux

Q.32 In figure, the switch S is closed so that a current flows in the iron-core inductor which has inductance L and the resistance R. When the switch is opened, a spark is obtained in it at the contacts. The spark is due to



(A) a slow flux change in L
(B) a sudden increase in the emf of the battery B
(C) a rapid flux change in L
(D) a rapid flux change in R

Q.33 In figure, a lamp P is in series with an iron-core inductor L. When the switch S is closed, the brightness of the lamp rises relatively slowly to its full brightness than it would do without the inductor. This is due to



(A) the low resistance of P
(B) the induced-emf in L
(C) the low resistance of L
(D) the high voltage of the battery B

Q.34 Two coil A and B have coefficient of mutual inductance M = 2H. The magnetic flux passing through coil A changes by 4 Weber in 10 seconds due to the change in current in B. Then
(A) change in current in B in this time interval is 0.5 A
(B) the change in current in B in this time interval is 2A
(C) the change in current in B in this time interval is 8A
(D) a change in current of 1 A in coil A will produce a change in flux passing through B by 4 Weber.

Q.35 Which of the following is true for an ideal transformer
(A) Total magnetic flux linked with primary coil equals flux linked with secondary coil
(B) flux per turn in primary is equal to flux per turn in secondary
(C) induced emf in secondary coil equals induced emf in primary
(D) power associated with primary coil at any moment equals power associated with secondary coil

Q.36 A circuit has three elements, a resistance of 11W, a coil of inductive resistance 120W and a capacitive reactance of 120W in series and connected to an A.C. source of 110 V, 60 Hz. Which of the three elements have minimum potential difference?
(A) Resistance (B) Capacitance
(C) Inductor (D) All will have equal potential difference

Q.37 The reactance of a circuit is zero. It is possible that the circuit contains :
(A) an inductor and a capacitor (B) an inductor but no capacitor
(C) a capacitor but no inductor (D) neigher an inductor nor a capacitor.

Q.38 In a series R-L-C circuit, the frequency of the source is half of the resonance frequency. The nature of the circuit will be
(A) capacitive (B) inductive (C) purely resistive (D) data insufficient

Q.39 An a.c. source of voltage V and of frequency 50 Hz is connected to an inductor of 2H and negligible resistance. A current of r.m.s. value I flows in the coil. When the frequency of the voltage is changed to 400 Hz keeping the magnitude of V the same, the current is now
(A) $8I$ in phase with V (B) $4I$ and leading by 90° from V
(C) $I/4$ and lagging by 90° from V (D) $I/8$ and lagging by 90° from V

ANSWER KEY

ONLY ONE OPTION IS CORRECT

Q.1	B	Q.2	C	Q.3	C	Q.4	A	Q.5	B	Q.6	B	Q.7	A
Q.8	A	Q.9	A	Q.10	B	Q.11	C	Q.12	C	Q.13	C	Q.14	A
Q.15	D	Q.16	C	Q.17	A	Q.18	D	Q.19	B	Q.20	D	Q.21	D
Q.22	B	Q.23	C	Q.24	A	Q.25	D	Q.26	A	Q.27	A	Q.28	C
Q.29	C	Q.30	B	Q.31	D	Q.32	B	Q.33	D	Q.34	D	Q.35	A
Q.36	A	Q.37	B	Q.38	A	Q.39	C	Q.40	A	Q.41	B	Q.42	D
Q.43	A	Q.44	C	Q.45	A	Q.46	A	Q.47	D	Q.48	B	Q.49	D
Q.50	B	Q.51	A	Q.52	C	Q.53	B	Q.54	A	Q.55	C	Q.56	A
Q.57	C	Q.58	A	Q.59	A	Q.60	A	Q.61	B	Q.62	B	Q.63	C
Q.64	A	Q.65	B	Q.66	A	Q.67	D	Q.68	D	Q.69	B	Q.70	C
Q.71	A	Q.72	A	Q.73	C	Q.74	B	Q.75	D	Q.76	A	Q.77	C
Q.78	D	Q.79	D	Q.80	C	Q.81	D	Q.82	A	Q.83	D	Q.84	C
Q.85	B	Q.86	D	Q.87	B	Q.88	B	Q.89	A	Q.90	C	Q.91	A
Q.92	D	Q.93	B	Q.94	C	Q.95	D	Q.96	C	Q.97	D	Q.98	A
Q.99	B	Q.100	D	Q.101	D	Q.102	C	Q.103	C	Q.104	B	Q.105	C

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	B	Q.2	C	Q.3	C	Q.4	B
Q.5	B	Q.6	A,C,D	Q.7	A	Q.8	A
Q.9	B	Q.10	B,C	Q.11	C	Q.12	B,D
Q.13	A,B	Q.14	B	Q.15	A	Q.16	D
Q.17	A,B,C,D	Q.18	B,D	Q.19	C	Q.20	D
Q.21	B,D	Q.22	A,C	Q.23	D	Q.24	A,B,C
Q.25	A,B,C	Q.26	D	Q.27	B,D	Q.28	D
Q.29	A	Q.30	A	Q.31	A	Q.32	C
Q.33	B	Q.34	B	Q.35	B,D	Q.36	A
Q.37	A,D	Q.38	A	Q.39	D		

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

ELECTROSTATICS

CONTENTS

KEY CONCEPTS

1. *ELECTRIC CHARGE*

Charge of a material body is that possesion (acquired or natural) due to which it strongly interacts with other material body. It can be postive or negative. S.I. unit is coulomb. Charge is quantized, conserved, and additive.

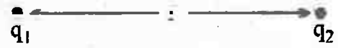
2. *COULOMB'S LAW* : $F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^2}$. In vector form $\vec{F}=\frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^3}\vec{r}$ where

ε_0 = permittivity of free space = $8.85 \times 10^{-12}\ N^{-1}\ m^{-2}\ c^2$ or F/m and

ε_r = Relative permittivity of the medium = Spec. Inductive Capacity = Dielectric Const.

ε_r = 1 for air (vacuum) = ∞ for metals $\varepsilon_0\varepsilon_r$ = Absolute permittivity of the medium

NOTE : The Law is applicable only for static and point charges.
Only applicable to static charges as moving charges may result magnetic interaction also and only for point charges as if charges are extended, induction may change the charge distribution.



3. *PRINCIPLE OF SUPER POSITION*

Force on a point charge due to many charges is given by $\vec{F}=\vec{F}_1+\vec{F}_2+\vec{F}_3+$.........

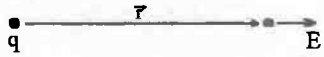
NOTE : The force due to one charge is not affected by the presence of other charges.

4. *ELECTRIC FIELD, ELECTRIC INTENSITY OR ELECTRIC FIELD STRENGTH (VECTOR QUANTITY)*

"The physical field where a charged particle, irrespective of the fact whether it is in motion or at rest, experiences force is called an electric field". The direction of the field is the direction of the force experienced by a positively charged particle & the magnitude of the field (electric intensity) is the force experienced by the particle carrying unit charge $\vec{E} = \lim_{q\to 0}\frac{\vec{F}}{q}$ unit is NC^{-1}; S.I. unit is V/m here $\lim_{q\to 0}$ represents that this charge does not alter the magnitude of electric field. Due to charge induction on the source of electric field.

5. *ELECTRIC FIELD DUE TO*

(i) Point charge : $\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^3}\vec{r}$ (vector form)



Where $\vec{r}$ = vector drawn from the source charge to the point .

(ii) Continuous charge distribution $\vec{E}=\frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r^2}\hat{r}=\int d\vec{E}$; $d\vec{E}$ = electric field due to an elementry charge

. **Note** $E\neq\int dE$ because E is a vector quantity .

$dq = \lambda\ dl$ (for line charge) = $\sigma\ ds$ (for surface charge) = $\rho\ dv$ (for volume charge) In general λ, σ & ρ are linear, surface and volume charge densities respectively.

(iii) Infinite line of charge $\vec{E} = \frac{2k\lambda}{r}$ where r = perpendicular distance of the point from the line charge .

(iv) Semi ∞ line of charge $\vec{E} = \frac{\sqrt{2}k\lambda}{r}$ as, $E_x = \frac{k\lambda}{r}$ & $E_y = \frac{k\lambda}{r}$ at a point above the end of wire at an angle 45° .

(v) Uniformly charged ring , $E_{centre} = 0$, $E_{axis} = \frac{kQx}{(x^2+R^2)^{3/2}}$

(vi) Electric field is maximum when $\frac{dE}{dx} = 0$ for a point on the axis of the ring. Here we get $x = R/\sqrt{2}$.

(vii) Infinite non conducting sheet of charge $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ where

$\hat{n}$ = unit normal vector to the plane of sheet, where σ is surface charge density

(viii) ∞ charged conductor sheet having surface charge density σ on both surfaces $E = \sigma/\varepsilon_0$.

(ix) Just outside a conducting surface charged with a surface charge density σ, electric field is always given as $E = \sigma/\epsilon_0$.

(x) Uniformly charged solid sphere (Insulating material) $E_{out} = \frac{Q}{4\pi\varepsilon_0 r^2}$; $r \geq R$,

Behaves as a point charge situated at the centre for these points $E_{in} = \frac{Qr}{4\pi\varepsilon_0 R^3} = \frac{\rho r}{3\varepsilon_0}$;

$r < R$ where ρ = volume charge density

(xi) Uniformly charged spherical shell (conducting or non-donducting) or uniformly charged solid conducting sphere . $E_{out} = \frac{Q}{4\pi\varepsilon_0 r^2}$; $r > R$

Behaves as a point charge situated at the centre for these points $E_{in} = 0$; $r < R$

(xii) uniformly charged cylinder with a charge density ρ is -(radius of cylinder = R) for $r < R$

$E_m = \frac{\rho r}{2\epsilon_0}$; for $r > R$ $\qquad E = \frac{\rho R^2}{2\epsilon_0 r}$

(xiii) Uniformly charged cylinderical shell with surface charge density σ is

for $r < R$ $E_m = 0$; for $r > R$ $E = \frac{\rho r}{\epsilon_0 r}$

6. ***ELECTRIC LINES OF FORCE (ELF)***

The line of force in an electric field is a hypothetical line, tangent to which at any point on it represents the direction of electric field at the given point.

Properties of (ELF) :

(i) Electric lines of forces never intersects .
(ii) ELF originates from positive charge or ∞ and terminate on a negative charge of infinity .
(iii) Preference of termination is towards a negative charge .
(iv) If an ELF is originated, it must require termination either at a negetive charge or at ∞ .
(v) Quantity of ELF originated or terminated from a charge or on a charge is proportional to the magnitude of charge.

7. ***ELECTROSTATIC EQUILIBRIUM***

Position where net force (or net torque) on a charge(or electric dipole) = 0

(i) **Stable Equilibrium :** If charge is displaced by a small distance the charge comes (or tries to come back) to the equilibrium .

(ii) **Unstable Equilibrium :** If charge is displaced by a small distance the charge does not return to the equilibrium position.

8. ***ELECTRIC POTENTIAL** (Scalar Quantity)*

"Work done by external agent to bring a unit positive charge(without accelaration) from infinity to a point in an electric field is called electric potential at that point".

If $W_{\infty r}$ is the work done to bring a charge q (very small) from infinity to a point then potential at that point is $V = \frac{(W_{\infty r})_{ext}}{q}$; S.I. unit is volt (= 1 J/C)

9. ***POTENTIAL DIFFERENCE***

$V_{AB} = V_A - V_B = \frac{(W_{BA})_{ext}}{q}$. V_{AB} = p.d. between point A & B.

W_{BA} = w.d. by external source to transfer a point charge q from B to A (Without acceleration).

10. ***ELECTRIC FIELD & ELECTRIC POINTENIAL***

$\vec{E} = -\text{grad } V = -\nabla V$ {read as gradient of V} grad $= \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$;

Used when EF varies in three dimensional coordinate system.

For finding potential difference between two points in electric field, we use –

$$V_A - V_B = -\int_A^B \vec{E}.\vec{dt}$$ if E is varying with distance

if E is constant & here d is the distance between points A and B.

11. ***POTENTIAL DUE TO***

(i) a point charge $V = \frac{Q}{4\pi\varepsilon_0 r}$ **(ii)** many charges $V = \frac{q_1}{4\pi\varepsilon_0 r_1} + \frac{q_2}{4\pi\varepsilon_0 r_2} + \frac{q_3}{4\pi\varepsilon_0 r_3} + \ldots\ldots$

(iii) continuous charge distribution $V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$

(iv) spherical shell (conducting or non conducting) or solid conducting sphere

$$V_{out} = \frac{Q}{4\pi\varepsilon_0 r} \ ; \ (r \geq R) \ , \quad V_{in} = \frac{Q}{4\pi\varepsilon_0 R} \ ; \ (r \leq R)$$

(v) non conducting uniformly charged solid sphere :

$$V_{out} = \frac{Q}{4\pi\varepsilon_0 r} \ ; \ (r \geq R) \ , \quad V_{in} = \frac{1}{2}\frac{Q(3R^2 - r^2)}{4\pi\varepsilon_0 R} \ , \ (r \leq R)$$

12. ***EQUIPOTENTIAL SURFACE AND EQUIPOTENTIAL REGION***

In an electricfield the locus of points of equal potential is called an equipotential surface. An equipotential surface and the electric field meet at right angles.

The region where E = 0, Potential of the whole region must remain constant as no work is done in displacement of charge in it. It is called as equipotential region like conducting bodies.

13. ***MUTUAL POTENTIAL ENERGY OR INTERACTION ENERGY***

"The work to be done to integrate the charge system."

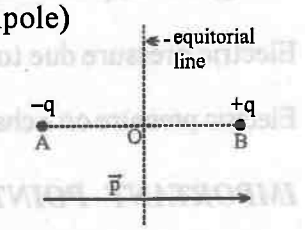
For 2 particle system $U_{mutual} = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r}$

For 3 particle system $U_{mutual} = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r_{12}} + \dfrac{q_2 q_3}{4\pi\varepsilon_0 r_{23}} + \dfrac{q_3 q_1}{4\pi\varepsilon_0 r_{31}}$

For n particles there will be $\dfrac{n(n-1)}{2}$ terms. Total energy of a system $= U_{self} + U_{mutual}$

14. P.E. of charge q in potential field U = qV. Interaction energy of a system of two charges $U = q_1V_2 = q_2V_1$.

15. ***ELECTRIC DIPOLE.*** O is mid point of line AB (centre of the dipole)



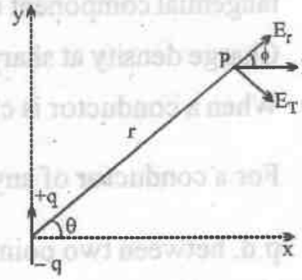
(a) on the axis (except points on line AB)

$\vec{E} = \dfrac{\vec{p}r}{2\pi\varepsilon_0[r^2 - (a^2/4)]^2} \simeq \dfrac{\vec{p}}{2\pi\varepsilon_0 r^3}$ (if $r << a$)

$\vec{p} = q\vec{a}$ = Dipole moment,

r = distance of the point from the centre of dipole

(b) on the equitorial ; $\vec{E} = \dfrac{\vec{p}}{4\pi\varepsilon_0[r^2 + (a^2/4)]^{3/2}} \simeq \dfrac{\vec{p}}{4\pi\varepsilon_0 r^3}$



(c) At a general point P(r, θ) in polar co-ordinate system is

Radial electric field $E_r = \dfrac{2kp\sin\theta}{r^3}$

Tangentral electric field $E_T = \dfrac{kp\cos\theta}{r^3}$

Net electric field at P is $E_{net} = \sqrt{E_r^2 + E_T^2} = \dfrac{kp}{r^3}\sqrt{1 + 3\sin^2\theta}$

Potential at point P is $V_P = \dfrac{kp\sin\theta}{r^2}$

NOTE : If θ is measured from axis of dipole. Then sinθ and cosθ will be interchanged.

(d) Dipole $V = \dfrac{P\theta}{4\pi\varepsilon_0 r^2} - \dfrac{\vec{p}.\vec{r}}{4\pi\varepsilon_0 r^3}$ $\vec{p} = q\vec{a}$ electric dipole moment . If θ is angle between $\vec{p}$ and reaches vector of the point.

(e) **Electric Dipole in uniform electric field :** torque $\vec{\tau} = \vec{p} \times \vec{E}$; $\vec{F} = 0$.

Work done in rotation of dipole is $w = PE(\cos\theta_1 - \cos\theta_2)$

(f) P.E. of an electric dipole in electric field $U = -\vec{p}.\vec{E}$.

(g) Force on a dipole when placed in a non uniform electric field is $F = -\dfrac{d}{dx}(-\vec{P}.\vec{E})\hat{i} = \vec{P}.\dfrac{d\vec{E}}{dx}\hat{i}$.

16. ***ELECTRIC FLUX***

(i) For uniform electric field; $\phi = \vec{E}.\vec{A} = EA\cos\theta$ where θ = angle between $\vec{E}$ & area vector ($\vec{A}$). Flux is contributed only due to the component of electric field which is perpendicular to the plane.

(ii) If $\vec{E}$ is not uniform throughout the area A, then $\phi = \int \vec{E}.d\vec{A}$

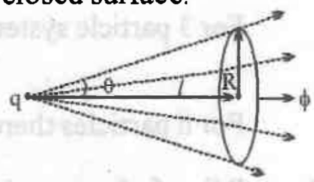
17. *GAUSS'S LAW* (Applicable only to closed surface) " Net flux emerging out of a closed surface is $\frac{q}{\varepsilon_0}$." $\phi = \oint \vec{E} d\vec{A} = \frac{q}{\varepsilon_0}$ q = net charge enclosed by the closed surface.

ϕ does not depend on the
(i) shape and size of the closed surface
(ii) The charges located outside the closed surface.

CONCEPT OF SOLID ANGLE :

Flux of charge q having through the circle of radius R is

$$\phi = \frac{q/\epsilon_0}{4\pi} \times \Omega = \frac{q}{2\epsilon_0}(1 - \cos\theta)$$



Solid angle of coneof half angle θ is $\Omega = 2\pi(1 - \cos\theta)$

18. Energy stored p.u. volume in an electric field = $\frac{\varepsilon_0 E^2}{2}$

19. Electric pressure due to its own charge on a surface having charged density σ is $P_{ele} = \frac{\sigma^2}{2\varepsilon_0}$.

20. Electric pressure on a charged surface with charged density σ due to external electric field is $P_{ele} = \sigma E_1$

IMPORTANT POINTS TO BE REMEMBERED

(i) Electric field is always perpendicular to a conducting surface (or any equipotential surface). No tangential component on such surfaces.

(ii) Charge density at sharp points on a conductor is greater.

(iii) When a conductor is charged, the charge resides only on the surface.

(iv) For a conductor of any shape E (just outside) = $\frac{\sigma}{\varepsilon_0}$

(v) p.d. between two points in an electric field does not depend on the path joining them.

(vi) Potential at a point due to positive charge is positive & due to negative charge is negative.

(vii) Positive charge flows from higher to lower (i.e. in the direction of electric field) and negative charge from lower to higher (i.e. opposite to the electric field) potential.

(viii) When $\vec{p} \| \vec{E}$ the dipole is in stable equilibrium

(ix) $\vec{p} \| (-\vec{E})$ the dipole is in unstable equilibrium

(x) When a charged isolated conducting sphere is connected to an unchaged small conducting sphere then potential (and charge) remains almost same on the larger sphere while smaller is charged.

(xi) Self potential energy of a charged shell = $\frac{KQ^2}{2R}$.

(xii) Self potential energy of an insulating uniformly charged sphere = $\frac{3kQ^2}{5R}$.

(xiii) A spherically symmetric charge {i.e ρ depends only on r} behaves as if its charge is concentrated at its centre (for outside points).

(xiv) **Dielectric strength of material :** The minimum electric field required to ionise the medium or the maximum electric field which the medium can bear without breaking down.

EXERCISE # I

Q.1 A negative point charge 2q and a positive charge q are fixed at a distance l apart. Where should a positive test charge Q be placed on the line connecting the charge for it to be in equilibrium? What is the nature of the equilibrium with respect to longitudinal motions?

Q.2 Two particles A and B each carrying a charge Q are held fixed with a separation d between then A particle C having mass m ans charge q is kept at the midpoint of line AB. If it is displaced through a small distance x (x << d) perpendicular to AB,

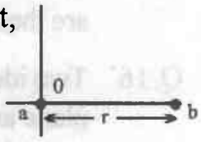
(a) then find the time period of the oscillations of C.

(b) If in the above question C is displaced along AB, find the time period of the oscillations of C.

Q.3 Draw E – r graph for 0 < r < b, if two point charges a & b are located r distance apart, when

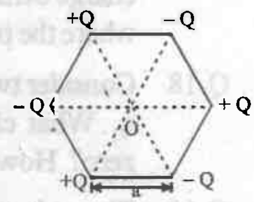
(i) both are + ve (ii) both are – ve

(iii) a is + ve and b is – ve (iv) a is – ve and b is + ve

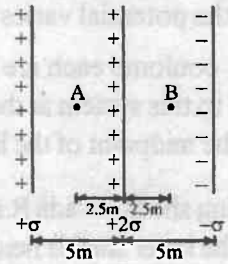


Q.4 A charge + 10^{-9} C is located at the origin in free space & another charge Q at (2, 0, 0). If the X–component of the electric field at (3, 1, 1) is zero, calculate the value of Q. Is the Y–component zero at (3, 1, 1)?

Q.5 Six charges are placed at the vertices of a regular hexagon as shown in the figure. Find the electric field on the line passing through O and perpendicular to the plane of the figure as a function of distance x from point O. (assume x >> a)

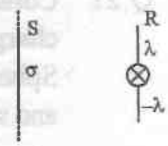


Q.6 The figure shows three infinite non-conducting plates of charge perpendicular to the plane of the paper with charge per unit area + σ, + 2σ and – σ. Find the ratio of the net electric field at that point A to that at point B.

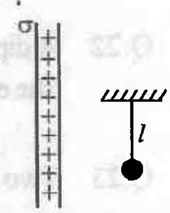


Q.7 A thin circular wire of radius r has a charge Q. If a point charge q is placed at the centre of the ring, then find the increase in tension in the wire.

Q.8 In the figure shown S is a large nonconducting sheet of uniform charge density σ. A rod R of length l and mass 'm' is parallel to the sheet and hinged at its mid point. The linear charge densities on the upper and lower half of the rod are shown in the figure. Find the angular acceleration of the rod just after it is released.



Q.9 A simple pendulum of length l and bob mass m is hanging in front of a large nonconducting sheet having surface charge density σ. If suddenly a charge +q is given to the bob & it is released from the position shown in figure. Find the maximum angle through which the string is deflected from vertical.



Q.10 A particle of mass m and charge – q moves along a diameter of a uniformly charged sphere of radius R and carrying a total charge + Q. Find the frequency of S.H.M. of the particle if the amplitude does not exceed R.

Q.11 A charge + Q is uniformly distributed over a thin ring with radius R. A negative point charge – Q and mass m starts from rest at a point far away from the centre of the ring and moves towards the centre. Find the velocity of this particle at the moment it passes through the centre of the ring.

Q.12 A spherical balloon of radius R charged uniformly on its surface with surface density σ. Find work done against electric forces in expanding it upto radius 2R.

Q.13 A point charge + q & mass 100 gm experiences a force of 100 N at a point at a distance 20 cm from a long infinite uniformly charged wire. If it is released find its speed when it is at a distance 40 cm from wire

Q.14 Consider the configuration of a system of four charges each of value +q. Find the work done by external agent in changing the configuration of the system from figure (i) to fig (ii).

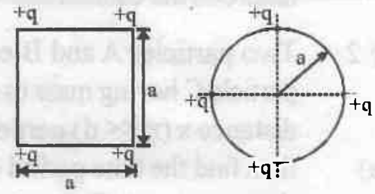
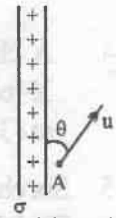


fig (i) fig (ii)

Q.15 There are 27 drops of a conducting fluid. Each has radius r and they are charged to a potential V_0. They are then combined to form a bigger drop. Find its potential.

Q.16 Two identical particles of mass m carry charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards the first from a large distance with an initial speed V. Find the closest distance of approach.

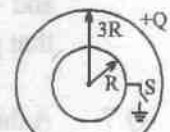
Q.17 A particle of mass m and negative charge q is thrown in a gravity free space with speed u from the point A on the large non conducting charged sheet with surface charge density σ, as shown in figure. Find the maximum distance from A on sheet where the particle can strike.



Q.18 Consider two concentric conducting spheres of radii a & b (b > a). Inside sphere has a positive charge q_1. What charge should be given to the outer sphere so that potential of the inner sphere becomes zero? How does the potential varies between the two spheres & outside ?

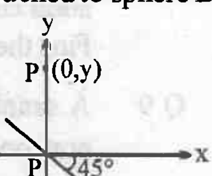
Q.19 Three charges 0.1 coulomb each are placed on the corners of an equilateral triangle of side 1 m. If the energy is supplied to this system at the rate of 1 kW, how much time would be required to move one of the charges onto the midpoint of the line joining the other two?

Q.20 Two thin conducting shells of radii R and 3R are shown in figure. The outer shell carries a charge +Q and the inner shell is neutral. The inner shell is earthed with the help of switch S. Find the charge attained by the inner shell.



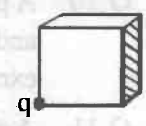
Q.21 Consider three identical metal spheres A, B and C. Spheres A carries charge + 6q and sphere B carries charge – 3q. Sphere C carries no charge. Spheres A and B are touched together and then separated. Sphere C is then touched to sphere A and separated from it. Finally the sphere C is touched to sphere B and separated from it. Find the final charge on the sphere C.

Q.22 A dipole is placed at origin of coordinate system as shown in figure, find the electric field at point P (0, y).

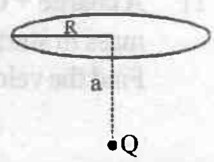


Q.23 Two point dipoles $p\hat{k}$ and $\frac{p}{2}\hat{k}$ are located at (0, 0, 0) and (1m, 0, 2m) respectively. Find the resultant electric field due to the two dipoles at the point (1m, 0, 0).

Q.24 The length of each side of a cubical closed surface is l. If charge q is situated on one of the vertices of the cube, then find the flux passing through shaded face of the cube.

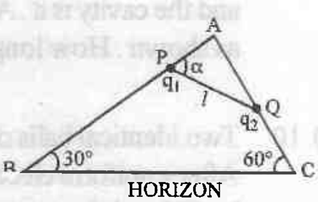


Q.25 A point charge Q is located on the axis of a disc of radius R at a distance a from the plane of the disc. If one fourth (1/4th) of the flux from the charge passes through the disc, then find the relation between a & R.



EXERCISE # II

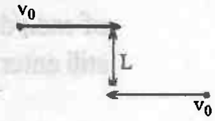
Q.1 A rigid insulated wire frame in the form of a right angled triangle ABC, is set in a vertical plane as shown. Two bead of equal masses m each and carrying charges q_1 & q_2 are connected by a cord of length l & slide without friction on the wires. Considering the case when the beads are stationary, determine.



(a) The angle α. (b) The tension in the cord &

(c) The normal reaction on the beads. If the cord is now cut, what are the values of the charges for which the beads continue to remain stationary.

Q.2 A proton and an α-particle are projected with velocity $v_0 = \sqrt{\frac{ke^2}{ml}}$ each, when they are far away from each other, as shown. The distance between their initial velocities is L. Find their closest approach distance, mass of proton=m; charge=+e, mass of α-particle = 4m, charge = + 2e.

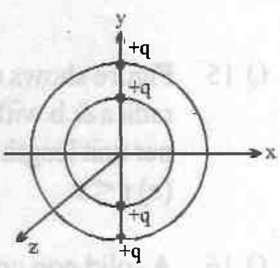


Q.3 A clock face has negative charges – q, – 2q, – 3q, ..., – 12q fixed at the position of the corresponding numerals on the dial. The clock hands do not disturb the net field due to point charges. At what time does the hour hand point in the same direction is electric field at the centre of the dial.

Q.4 A circular ring of radius R with uniform positive charge density λ per unit length is fixed in the Y–Z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point P $(\sqrt{3}R,0,0)$ on the positive X-axis directly towards O, with initial velocity v. Find the smallest value of the speed v such that the particle does not return to P.

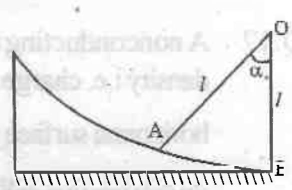
Q.5 2 small balls having the same mass & charge & located on the same vertical at heights h_1 & h_2 are thrown in the same direction along the horizontal at the same velocity v. The 1st ball touches the ground at a distance l from the initial vertical. At what height will the 2nd ball be at this instant? The air drag & the charges induced should be neglected.

Q.6 Two concentric rings of radii r and 2r are placed with centre at origin. Two charges +q each are fixed at the diametrically opposite points of the rings as shown in figure. Smaller ring is now rotated by an angle 90° about Z-axis then it is again rotated by 90° about Y-axis. Find the work done by electrostatic forces in each step. If finally larger ring is rotated by 90° about X-axis, find the total work required to perform all three steps.



Q.7 A positive charge Q is uniformly distributed throughout the volume of a dielectric sphere of radius R. A point mass having charge + q and mass m is fired towards the centre of the sphere with velocity v from a point at distance r (r > R) from the centre of the sphere. Find the minimum velocity v so that it can penetrate R/2 distance of the sphere. Neglect any resistance other than electric interaction. Charge on the small mass remains constant throughout the motion.

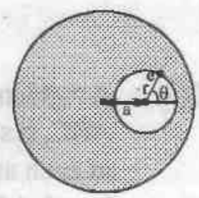
Q.8 An electrometer consists of vertical metal bar at the top of which is attached a thin rod which gets deflected from the bar under the action of an electric charge (fig.). The reading are taken on a quadrant graduated in degrees. The length of the rod is l and its mass is m. What will be the charge when the rod of such an electrometer is deflected through an angle α. Make the following assumptions :



(a) the charge on the electrometer is equally distributed between the bar & the rod

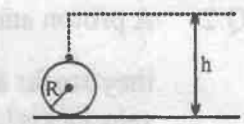
(b) the charges are concentrated at point A on the rod & at point B on the bar.

Q.9 A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at an angle $\theta = 45°$ as shown. How long will it take to touch the sphere again?



Q.10 Two identical balls of charges q_1 & q_2 initially have equal velocity of the same magnitude and direction. After a uniform electric field is applied for some time, the direction of the velocity of the first ball changes by 60° and the magnitude is reduced by half. The direction of the velocity of the second ball changes there by 90°. In what proportion will the velocity of the second ball changes ?

Q.11 Electrically charged drops of mercury fall from altitude h into a spherical metal vessel of radius R in the upper part of which there is a small opening. The mass of each drop is m & charge is Q. What is the number 'n' of last drop that can still enter the sphere. Given that the $(n + 1)^{th}$ drop just fails to enter the sphere.

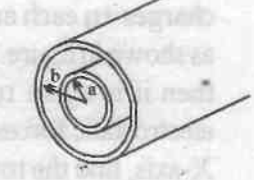


Q.12 Small identical balls with equal charges are fixed at vertices of regular 2004 - gon with side a. At a certain instant, one of the balls is released & a sufficiently long time interval later, the ball adjacent to the first released ball is freed The kinetic energies of the released balls are found to differ by K at a sufficiently long distance from the polygon. Determine the charge q of each part.

Q.13 The electric field in a region is given by $\vec{E} = \frac{E_0 x}{l}\hat{i}$. Find the charge contained inside a cubical volume bounded by the surfaces x = 0, x = a, y = 0, y = a, z = 0 and z = a. Take $E_0 = 5 \times 10^3$ N/C, $l = 2$cm and a = 1cm.

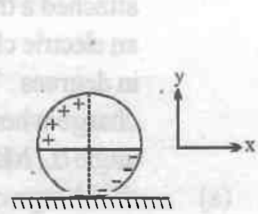
Q.14 2 small metallic balls of radii R_1 & R_2 are kept in vacuum at a large distance compared to the radii. Find the ratio between the charges on the 2 balls at which electrostatic energy of the system is minimum. What is the potential difference between the 2 balls? Total charge of balls is constant.

Q.15 Figure shows a section through two long thin concentric cylinders of radii a & b with $a < b$. The cylinders have equal and opposite charges per unit length λ. Find the electric field at a distance r from the axis for
(a) $r < a$ (b) $a < r < b$ (c) $r > b$



Q.16 A solid non conducting sphere of radius R has a non-uniform charge distribution of volume charge density, $\rho = \rho_0 \frac{r}{R}$, where ρ_0 is a constant and r is the distance from the centre of the sphere. Show that:
(a) the total charge on the sphere is $Q = \pi \rho_0 R^3$ and
(b) the electric field inside the sphere has a magnitude given by, $E = \frac{KQr^2}{R^4}$.

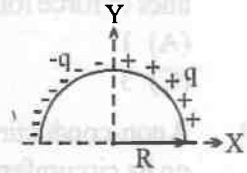
Q.17 A nonconducting ring of mass m and radius R is charged as shown. The charged density i.e. charge per unit length is λ. It is then placed on a rough nonconducting horizontal surface plane. At time t = 0, a uniform electric field $\vec{E} = E_0 i$ is switched on and the ring start rolling without sliding. Determine the friction force (magnitude and direction) acting on the ring, when it starts moving.



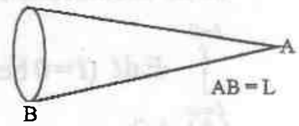
Q.18 Two spherical bobs of same mass & radius having equal charges are suspended from the same point by strings of same length. The bobs are immersed in a liquid of relative permittivity ε_r & density ρ_0. Find the density σ of the bob for which the angle of divergence of the strings to be the same in the air & in the liquid ?

Q.19 An electron beam after being accelerated from rest through a potential difference of 500 V in vacuum is allowed to impinge normally on a fixed surface. If the incident current is 100 μA, determine the force exerted on the surface assuming that it brings the electrons to rest. ($e = 1.6\times10^{-19}$ C ; $m = 9.0\times10^{-31}$ kg)

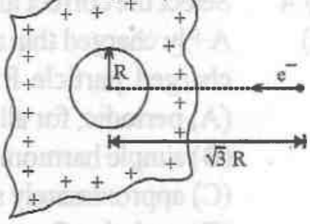
Q.20 Find the electric field at centre of semicircular ring shown in figure.



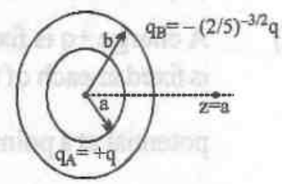
Q.21 A cone made of insulating material has a total charge Q spread uniformly over its sloping surface. Calculate the energy required to take a test charge q from infinity to apex A of cone. The slant length is L.



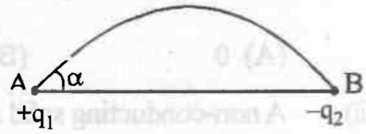
Q.22 An infinite dielectric sheet having charge density σ has a hole of radius R in it. An electron is released on the axis of the hole at a distance $\sqrt{3}$R from the centre. What will be the velocity which it crosses the plane of sheet. (e = charge on electron and m = mass of electron)



Q.23 Two concentric rings, one of radius 'a' and the other of radius 'b' have the charges +q and $-(2/5)^{-3/2}$ q respectively as shown in the figure. Find the ratio b/a if a charge particle placed on the axis at z = a is in equilibrium.



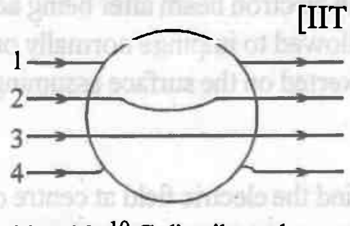
Q.24 Two charges $+q_1$ & $-q_2$ are placed at A and B respectively. A line of force emerges from q_1 at angle α with line AB. At what angle will it terminate at $-q_2$?



EXERCISE # III

Q.1 The magnitude of electric field $\vec{E}$ in the annular region of charged cylindrical capacitor
(A) Is same throughout
(B) Is higher near the outer cylinder than near the inner cylinder
(C) Varies as $(1/r)$ where r is the distance from the axis
(D) Varies as $(1/r^2)$ where r is the distance from the axis [IIT '96, 2]

Q.2 A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path (s) shown in figure as :



(A) 1 (B) 2
(C) 3 (D) 4 [IIT'96 , 2]

Q.3 A non-conducting ring of radius 0.5 m carries a total charge of 1.11×10^{-10} C distributed non-uniformly on its circumference producing an electric field E every where in space. The value of the line integral $\int_{\ell=\infty}^{\ell=0} -\vec{E}.d\vec{\ell}$ ($l = 0$ being centre of the ring) in volts is :
(A) +2 (B) −1 (C) −2 (D) zero[JEE '97, 1]

Q.4 Select the correct alternative : [JEE '98 2 + 2 + 2 = 6]

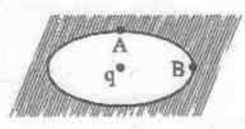
(i) A + ly charged thin metal ring of radius R is fixed in the xy–plane with its centre at the origin O . A – ly charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is:
(A) periodic, for all values of z_0 satisfying $0 < z_0 < \infty$
(B) simple harmonic, for all values of z_0 satisfying $0 < z_0 \le R$
(C) approximately simple harmonic, provided $z_0 << R$
(D) such that P crosses O & continues to move along the –ve z-axis towards $x = -\infty$

(ii) A charge +q is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$, ... ∞ on the x-axis & a charge −q is fixed at each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$, ... ∞ . Here x_0 is a +ve constant . Take the electric potential at a point due to a charge Q at a distance r from it to be $\frac{Q}{4\pi\epsilon_0 r}$. Then the potential at the origin due to the above system of charges is :
(A) 0 (B) $\frac{q}{8\pi\epsilon_0 x_0 \ell n2}$ (C) ∞ (D) $\frac{q\ell n2}{4\pi\epsilon_0 x_0}$

(iii) A non-conducting solid sphere of radius R is uniformly charged . The magnitude of the electric field due to the sphere at a distance r from its centre :
(A) increases as r increases, for $r < R$ (B) decreases as r increases, for $0 < r < \infty$
(C) decreases as r increases, for $R < r < \infty$ (D) is discontinuous at $r = R$.

Q.5 A conducting sphere S_1 of radius r is attached to an insulating handle . Another conducting sphere S_2 of radius R is mounted on an insulating stand . S_2 is initially uncharged . S_1 is given a charge Q, brought into contact with S_2 & removed, S_1 is recharged such that the charge on it is again Q & it is again brought into contact with S_2 & removed. This procedure is repeated n times.
(a) Find the electrostatic energy of S_2 after n such contacts with S_1.
(b) What is the limiting value of this energy as $n \to \infty$? [JEE '98, 7 + 1]

Q.6(i) An ellipsoidal cavity is carved within a perfect conductor. A positive charge q is placed at the center of the cavity. The points A & B are on the cavity surface as shown in the figure. Then :



(A) electric field near A in the cavity = electric field near B in the cavity
(B) charge density at A = charge density at B
(C) potential at A = potential at B
(D) total electric field flux through the surface of the cavity is q/ϵ_0 . [JEE '99, 3]

(ii) A non-conducting disc of radius a and uniform positive surface charge density σ is placed on the ground, with its axis vertical. A particle of mass m & positive charge q is dropped, along the axis of the disc, from a height H with zero initial velocity. The particle has $\frac{q}{m} = \frac{4\varepsilon_0 g}{\sigma}$.

(a) Find the value of H if the particle just reaches the disc.

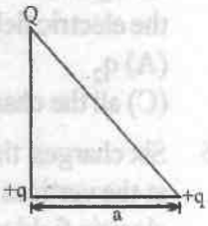
(b) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

[JEE '99, 5 + 5]

Q.7(a) The dimension of $\left(\frac{1}{2}\right)e_0 E^2$ (e_0 : permittivity of free space ; E : electric field) is :

(A) MLT^{-1} (B) ML^2T^{-2} (C) MLT^{-2} (D) ML^2T^{-1} (E) $ML^{-1}T^{-2}$

(b) Three charges Q, +q and +q are placed at the vertices of a right-angled isosceles triangle as shown. The net electrostatic energy of the configuration is zero if Q is equal to : [JEE 2000(Scr) 1 + 1]

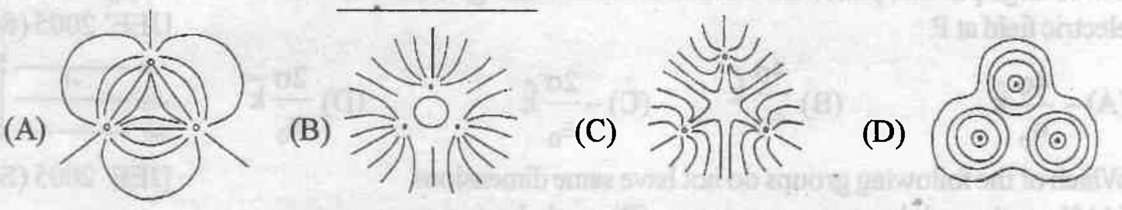


(A) $\frac{-q}{1+\sqrt{2}}$ (B) $\frac{-2q}{2+\sqrt{2}}$

(C) $-2q$ (D) $+q$

(c) Four point charges $+8\ \mu C$, $-1\ \mu C$, $-1\ \mu C$ and $+8\ \mu C$, are fixed at the points, $-\sqrt{\frac{27}{2}}$ m, $-\sqrt{\frac{3}{2}}$ m, $+\sqrt{\frac{3}{2}}$ m and $+\sqrt{\frac{27}{2}}$ m respectively on the y-axis. A particle of mass 6×10^{-4} kg and of charge $+0.1\ \mu C$ moves along the $-x$ direction. Its speed at $x = +\infty$ is v_0. Find the least value of v_0 for which the particle will cross the origin. Find also the kinetic energy of the particle at the origin. Assume that space is gratity free. (Given : $1/(4\pi\varepsilon_0) = 9 \times 10^9\ Nm^2/C^2$) [JEE 2000, 10]

Q.8 Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting lines of force should be sketched as in [JEE 2001 (Scr)]



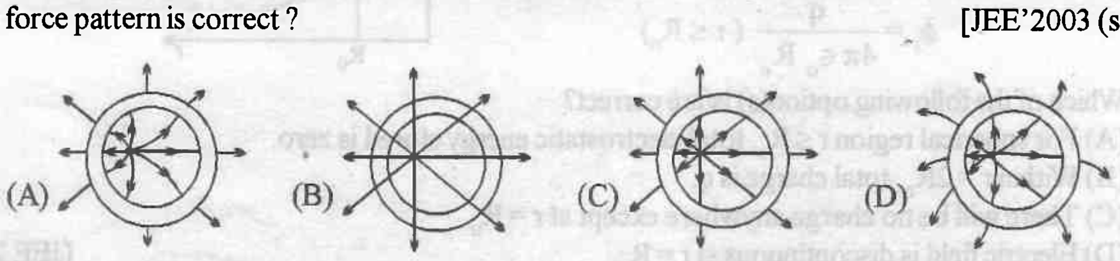
Q.9 A small ball of mass 2×10^{-3} Kg having a charge of 1 μC is suspended by a string of length 0. 8m. Another identical ball having the same charge is kept at the point of suspension. Determine the minimum horizontal velocity which should be imparted to the lower ball so tht it can make complete revolution.

[JEE 2001]

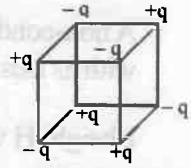
Q.10 Two equal point charges are fixed at $x = -a$ and $x = +a$ on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to

(A) x (B) x^2 (C) x^3 (D) 1/x [JEE 2002 (Scr), 3]

Q.11 A point charge 'q' is placed at a point inside a hollow conducting sphere. Which of the following electric force pattern is correct? [JEE'2003 (scr)]

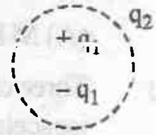


Q.12 Charges +q and –q are located at the corners of a cube of side a as shown in the figure. Find the work done to separate the charges to infinite distance. [JEE 2003]



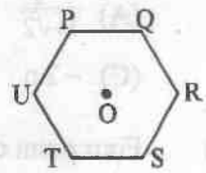
Q.13 A charge +Q is fixed at the origin of the co-ordinate system while a small electric dipole of dipole-moment $\vec{p}$ pointing away from the charge along the x-axis is set free from a point far away from the origin.
(a) calculate the K.E. of the dipole when it reaches to a point (d, 0)
(b) calculate the force on the charge +Q at this moment. [JEE 2003]

Q.14 Consider the charge configuration and a spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to [JEE 2004 (SCR)]



(A) q_2 (B) only the positive charges
(C) all the charges (D) $+q_1$ and $-q_1$

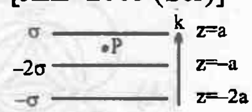
Q.15 Six charges, three positive and three negative of equal magnitude are to be placed at the vertices of a regular hexagon such that the electric field at O is double the electric field when only one positive charge of same magnitude is placed at R. Which of the following arrangements of charges is possible for P, Q, R, S, T and U respectively? [JEE 2004 (SCR)]



(A) +, -, +, -, -, + (B) +, -, +, -, +, – (C) +, +, -, +, -, – (D) –, +, +, –, +, –

Q.16 Two uniformly charged infinitely large planar sheet S_1 and S_2 are held in air parallel to each other with separation d between them. The sheets have charge distribution per unit area σ_1 and σ_2 (Cm^{-2}), respectively, with $\sigma_1 > \sigma_2$. Find the work done by the electric field on a point charge Q that moves from from S_1 towards S_2 along a line of length a (a < d) making an angle $\pi/4$ with the normal to the sheets. Assume that the charge Q does not affect the charge distributions of the sheets. [JEE 2004]

Q.17 Three large parallel plates have uniform surface charge densities as shown in the figure. What is the electric field at P. [JEE' 2005 (Scr)]



(A) $-\frac{4\sigma}{\epsilon_0}\hat{k}$ (B) $\frac{4\sigma}{\epsilon_0}\hat{k}$ (C) $-\frac{2\sigma}{\epsilon_0}\hat{k}$ (D) $\frac{2\sigma}{\epsilon_0}\hat{k}$

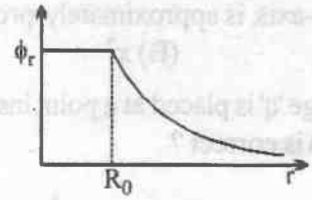
Q.18 Which of the following groups do not have same dimensions [JEE' 2005 (Scr)]
(A) Young's modulus, pressure, stress (B) work, heat, energy
(C) electromotive force, potential difference, voltage
(D) electric dipole, electric flux, electric field

Q.19 A conducting liquid bubble of radius a and thickness t (t <<a) is charged to potential V. If the bubble collapses to a droplet, find the potential on the droplet. [JEE 2005]

Q.20 The electrostatic potential (ϕ_r) of a spherical symmetric system, kept at origin, is shown in the adjacent figure, and given as

$$\phi_r = \frac{q}{4\pi \epsilon_o r} \quad (r \geq R_o)$$

$$\phi_r = \frac{q}{4\pi \epsilon_o R_o} \quad (r < R_o)$$



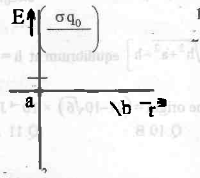
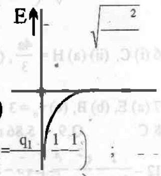
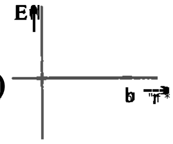
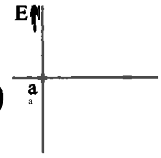
Which of the following option(s) is/are correct?
(A) For spherical region r < R_o, total electrostatic energy stored is zero.
(B) Within r = $2R_o$, total charge is q.
(C) There will be no charge anywhere except at r = R_o.
(D) Electric field is discontinuous at r = R_o. [JEE 2006]

ANSWER KEY

EXERCISE # I

Q.1 $a = l(1+\sqrt{2})$, the equilibrium will be stable

Q.2 (a) $\sqrt{\frac{m\pi^3\varepsilon_0 d^3}{Qq}}$ (b) $\sqrt{\frac{m\pi^3\varepsilon_0 d^3}{2Qq}}$

Q.3 (i)  (ii)  (iii)  (iv) 

Q.4 $-\left(\frac{3}{11}\right)^{3/2} 3\times10^{-9}$ C Q.5 0 Q.6 Q.7 $\frac{qQ}{8\pi^2\varepsilon_0 r^2}$

Q.8 $\frac{3\sigma\lambda}{2m\in_0}$ Q.9 $2\tan^{-1}\left(\frac{\sigma q}{2\varepsilon_0 mg}\right)$ Q.10 $\frac{1}{2\pi}\sqrt{\frac{qQ}{4\pi\varepsilon_0 mR^3}}$ Q.11 $\frac{2kQ}{mR}$

Q.12 $-\frac{\pi\sigma^2R^3}{}$ Q.13 $20\sqrt{ln2}$ Q.14 $-\frac{kq^2}{}(b-\sqrt{3})$ Q.15 $9V_0$

Q.16 $\frac{q}{m\pi\in_0 V}$ Q.17 $\frac{2\in_0 u\,m}{q\sigma}$ Q.18 (i) $q_2 = -\frac{b}{}q_1$; (ii) $V_r = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{a}\right)$ a<r<b ; $V_r = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{b}-\frac{1}{a}\right)$ r=b ; $V_r = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r}+\frac{q_2}{r}\right)$ r>b

Q.19 1.8×10^{-5} sec Q.20 $-Q/3$ Q.21 $1.125\,q$ Q.22 $\frac{kP}{}(-\hat{i}+2\hat{j})$

Q.23 $-kp$ Q.24 $\frac{}{24\in_0}$ Q.25 $a=\frac{R}{\sqrt{3}}$ Q.26 $\frac{Q}{2\varepsilon_0}$

EXERCISE # II

Q.1 (a) 60° (b) $mg + \frac{kq_1q_2}{}$ (c) $\sqrt{3}$ mg, mg . q_1 & q_2 should have unlike changes for the beads to remain stationaly & $q_1q_2 = -mg\,l^2/k$

Q.2 $\left(\frac{5+\sqrt{89}}{8}\right)$ Q.3 9.30 Q.4 $\frac{\lambda q}{2\pi\varepsilon_0 m}$ Q.5 $H_2 = h_1 + h_2 - g$

Q.6 $W_{first\ step} = \left(\frac{8}{3}-\frac{4}{\sqrt{5}}\right)\frac{Kq^2}{r}$, $W_{second\ step} = 0$, $W_{total} = 0$ Q.7 $\left[\frac{2KQq}{mR}\left(\frac{r-R}{r}\frac{3}{8}\right)\right]^{1/2}$

Q.8 $q = 4l\sqrt{4\pi\varepsilon_0 mg\sin}\ \sin\frac{\alpha}{2}$ Q.9 $\sqrt{\frac{6\sqrt{2}mr\in}{epa}}$ Q.10 $\sqrt{3}$

Q.11 $n = \frac{4\pi\varepsilon_0 mg(h-R)R}{}$ Q.12 $\sqrt{4\pi\varepsilon_0 Ka}$ Q.13 2.2×10^{-12}C Q.14 $\frac{q_2}{}\ R_2$

Q.15 0, $\frac{2K\lambda}{r}$, 0 Q.17 $\lambda R E_0 \hat{i}$ Q.18 $\sigma = \frac{\varepsilon_r \rho_0}{\varepsilon_r - 1}$ Q.19 7.5×10^{-9} N

Q.20 $-\frac{4kq}{\pi R^2}\hat{i}$ Q.21 $\frac{Qq}{2\pi \epsilon_0 L}$ Q.22 $v = \sqrt{\frac{\sigma e R}{m\varepsilon_0}}$ Q.23 2

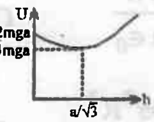
Q.24 $b = 2\sin^{-1}\left(\sin\frac{\alpha}{2}\sqrt{\frac{q_1}{q_2}}\right)$

EXERCISE # III

Q.1 C Q.2 D Q.3 A Q.4 (i) A, C, (ii) D, (iii) A, C

Q.5 (a) $U_2 = \frac{a^2Q^2}{8\pi\epsilon_0 R}\left(\frac{1-a^n}{1-a}\right)^2$ where $a = \frac{R}{r+R}$, (b) $U_2 (n \to \infty) = \frac{RQ^2}{8\pi\epsilon_0 r^2}$

Q.6 (i) C, (ii) (a) $H = \frac{4a}{3}$, (b) $U = mg\left[2\sqrt{h^2+a^2}-h\right]$ equilibrium at $h = \frac{a}{\sqrt{3}}$,



Q.7 (a) E, (b) B, (c) $v_0 = 3$ m/s ; K.E. at the origin $= \left(27-10\sqrt{6}\right) \times 10^{-4}$ J approx.2.5×10^{-4} J

Q.8 C Q.9 5.86 m/s Q.10 B Q.11 A

Q.12 $-\frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}\cdot\frac{4}{\sqrt{6}}\left[3\sqrt{3}-3\sqrt{6}-\sqrt{2}\right]$

Q.13 (a) $K.E = \frac{P}{4\pi\varepsilon_0}\frac{Q}{d^2}$, (b) $\frac{QP}{2\pi\varepsilon_0 d^3}$ along positive x-axis Q.14 C

Q.15 -, +, +, -, +, - Q.16 $\frac{(\sigma_1-\sigma_2)Qa}{2\sqrt{2}\,\varepsilon_0}$ Q.17 C Q.18 D Q.19 $V' = \left(\frac{a}{3t}\right)^{1/3}.V$

Q.20 A,B,C,D

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

ELECTROSTATICS

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

Q.1 Two identical conducting spheres, having charges of opposite sign, attract each other with a force of 0.108 N when separated by 0.5 m. The spheres are connected by a conducting wire, which is then removed, and thereafter, they repel each other with a force of 0.036 N. The initial charges on the spheres are

(A) $\pm 5 \times 10^{-6}$ C and $\mp$ 15 $\times 10^{-6}$ C (B) $\pm 1.0 \times 10^{-6}$ C and $\mp$ 3.0 $\times 10^{-6}$ C

(C) $\pm 2.0 \times 10^{-6}$ C and $\mp$ 6.0 $\times 10^{-6}$ C (D) $\pm 0.5 \times 10^{-6}$ C and $\mp$ 1.5 $\times 10^{-6}$ C

Q.2 A point charge 50μC is located in the XY plane at the point of position vector $\vec{r}_0 = 2\hat{i} + 3\hat{j}$. What is the electric field at the point of position vector $\vec{r} = 8\hat{i} - 5\hat{j}$

(A) 1200V/m (B) 0.04V/m (C) 900V/m (D) 4500 V/m

Q.3 A point charge q is placed at origin. Let $\vec{E}_A$, $\vec{E}_B$ and $\vec{E}_C$ be the electric field at three points A (1, 2, 3), B (1, 1, – 1) and C (2, 2, 2) due to charge q. Then

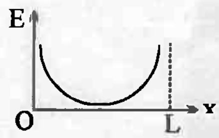
[i] $\vec{E}_A \perp \vec{E}_B$ [ii] $|\vec{E}_B| = 4|\vec{E}_C|$

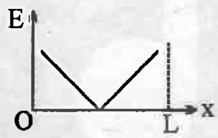
select the correct alternative

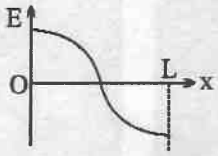
(A) only [i] is correct (B) only [ii] is correct

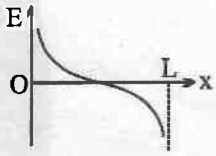
(C) both [i] and [ii] are correct (D) both [i] and [ii] are wrong

Q.4 Two identical point charges are placed at a separation of l. P is a point on the line joining the charges, at a distance x from any one charge. The field at P is E. E is plotted against x for values of x from close to zero to slightly less than l. Which of the following best represents the resulting curve?

(A) 

(B) 

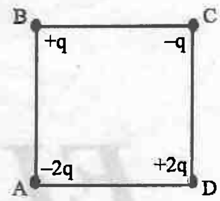
(C) 

(D) 

Q.5 A particle of mass m and charge Q is placed in an electric field E which varies with time t ass $E = E_0 \sin\omega t$. It will undergo simple harmonic motion of amplitude

(A) $\dfrac{QE_0^2}{m\omega^2}$ (B) $\dfrac{QE_0}{m\omega^2}$ (C) $\sqrt{\dfrac{QE_0}{m\omega^2}}$ (D) $\dfrac{QE_0}{m\omega}$

Q.6 Four charges are arranged at the corners of a square ABCD, as shown. The force on a +ve charge kept at the centre of the square is



(A) zero (B) along diagonal AC

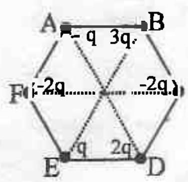
(C) along diagonal BD (D) perpendicular to the side AB

Q.7 Two free positive charges 4q and q are a distance l apart. What charge Q is needed to achieve equilibrium for the entire system and where should it be placed form charge q?

(A) $Q = \dfrac{4}{9}q$ (negative) at $\dfrac{l}{3}$ (B) $Q = \dfrac{4}{9}q$ (positive) at $\dfrac{l}{3}$

(C) $Q = q$ (positive) at $\dfrac{l}{3}$ (D) $Q = q$ (negative) at $\dfrac{l}{3}$

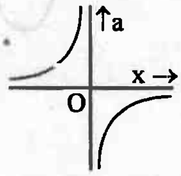
Q.8 Six charges are placed at the corner of a regular hexagon as shown. If an electron is placed at its centre O, force on it will be:

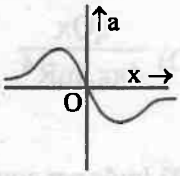


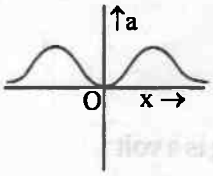
(A) Zero (B) Along OF

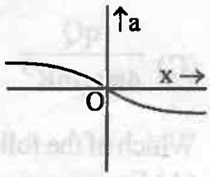
(C) Along OC (D) None of these

Q.9 Two identical positive charges are fixed on the y-axis, at equal distances from the origin O. A particle with a negative charge starts on the x-axis at a large distance from O, moves along the + x-axis, passes through O and moves far away from O. Its acceleration a is taken as positive along its direction of motion. The particle's acceleration a is plotted against its x-coordinate. Which of the following best represents the plot?

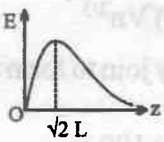
(A) 

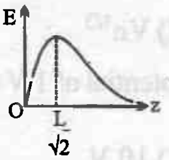
(B) 

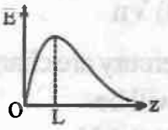
(C) 

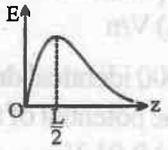
(D) 

Q.10 Four equal positive charges are fixed at the vertices of a square of side L. Z-axis is perpendicular to the plane of the square. The point z = 0 is the point where the diagonals of the square intersect each other. The plot of electric field due to the four charges, as one moves on the z-axis.

(A) 

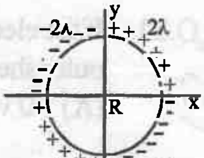
(B) 

(C) 

(D) 

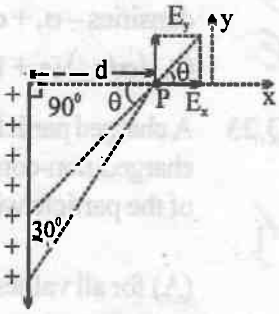
Q.11 A nonconducting ring of radius R has uniformly distributed positive charge Q. A small part of the ring, of length d, is removed (d << R). The electric field at the centre of the ring will now be
(A) directed towards the gap, inversely proportional to R^3.
(B) directed towards the gap, inversely proportional to R^2.
(C) directed away from the gap, inversely proportional to R^3.
(D) directed away from the gap, inversely proportional to R^2.

Q.12 The charge per unit length of the four quadrant of the ring is 2λ, -2λ, λ and $-\lambda$ respectively. The electric field at the centre is



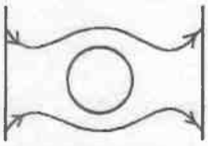
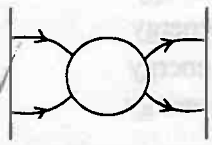
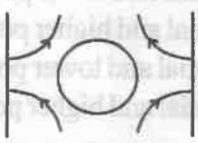
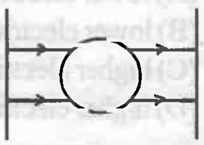
(A) $-\frac{\lambda}{2\pi\varepsilon_0 R}\hat{i}$ (B) $\frac{\lambda}{2\pi\varepsilon_0 R}\hat{j}$ (C) $\frac{\sqrt{2}\,\lambda}{4\pi\varepsilon_0 R}\hat{i}$ (D) None

Q.13 The direction (θ) of $\vec{E}$ at point P due to uniformly charged finite rod will be
(A) at angle 30° from x-axis
(B) 45° from x - axis
(C) 60° from x-axis
(D) none of these

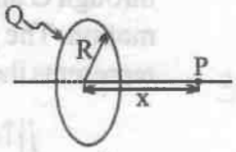


Q.14 Two equal negative charges are fixed at the points [0, a] and [0, –a] on the y-axis. A positive charge Q is released from rest at the points [2a, 0] on the x-axis . The charge Q will
(A) execute simple harmonic motion about the origin
(B) move to the origin and remain at rest
(C) move to infinity
(D) execute oscillatory but not simple harmonic motion.

Q.15 An uncharged sphere of metal placed inside a charged parallel plate capacitor. The lines of force look like

(A)  (B)  (C)  (D) 

Q.16 A small particle of mass m and charge –q is placed at point P and released. If R >> x, the particle will undergo oscillations along the axis of symmetry with an angular frequency that is equal to



(A) $\sqrt{\frac{qQ}{4\pi\varepsilon_0 mR^3}}$ (B) $\sqrt{\frac{qQx}{4\pi\varepsilon_0 mR^4}}$

(C) $\frac{qQ}{4\pi\varepsilon_0 mR^3}$ (D) $\frac{qQx}{4\pi\varepsilon_0 mR^4}$

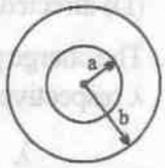
Q.17 Which of the following is a volt :
(A) Erg per cm (B) Joule per coulomb
(C) Erg per ampere (D) Newton / (coulomb x m^2)

Q.18 n small drops of same size are charged to V volts each. If they coalesce to form a signal large drop, then its potential will be
(A) V/n (B) Vn (C) $Vn^{1/3}$ (D) $Vn^{2/3}$

Q.19 1000 identical drops of mercury are charged to a potential of 1 V each. They join to form a single drop. The potential of this drop will be
(A) 0.01 V (B) 0.1 V (C) 10 V (D) 100 V

Q.20 Potential difference between centre & the surface of sphere of radius R and uniform volume charge density ρ within it will be :
(A) $\frac{\rho R^2}{6\epsilon_0}$ (B) $\frac{\rho R^2}{4\epsilon_0}$ (C) 0 (D) $\frac{\rho R^2}{2\epsilon_0}$

Q.21 If the electric potential of the inner metal sphere is 10 volt & that of the outer shell is 5 volt, then the potential at the centre will be :

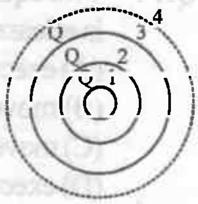


(A) 10 volt (B) 5 volt (C) 15 volt (D) 0

Q.22 Three concentric metallic spherical shell A, B and C or radii a, b and c (a < b < c) have surface charge densities – σ, + σ, and – σ respectively. The potential of shell A is :
(A) (σ/ε_0) [a + b – c] (B) (σ/ε_0) [a – b + c] (C) (σ/ε_0) [b – a – c] (D) none

Q.23 A charged particle having some mass is resting in equilibrium at a height H above the centre of a uniformly charged non-conducting horizontal ring of radius R. The force of gravity acts downwards. The equilibrium of the particle will be stable
(A) for all values of H (B) only if H > $\frac{R}{\sqrt{2}}$ (C) only if H < $\frac{R}{\sqrt{2}}$ (D) only if H = $\frac{R}{\sqrt{2}}$

Q.24 An infinite number of concentric rings carry a charge Q each alternately positive and negative. Their radii are 1, 2, 4, 8...... meters in geometric progression as shown in the figure. The potential at the centre of the rings will be



(A) zero (B) $\frac{Q}{12\pi\varepsilon_0}$ (C) $\frac{Q}{8\pi\varepsilon_0}$ (D) $\frac{Q}{6\pi\varepsilon_0}$

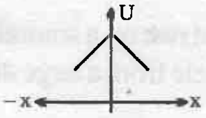
Q.25 When a negative charge is released and moves in electric field, it moves toward a position of
(A) lower electric potential and lower potential energy
(B) lower electric potential and higher potential energy
(C) higher electric potential and lower potential energy
(D) higher electric potential and higher potential energy

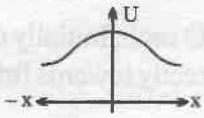
Q.26 A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at the centre of the sphere is
(A) 0 V
(B) 10 V
(C) same as at point 5 cm away from the surface out side sphere.
(D) same as a point 25 cm away from the surface.

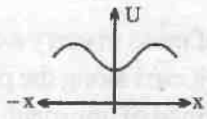
Q.27 A solid sphere of radius R is charged uniformly. At what distance from its surface is the electrostatic potential half of the potential at the centre?
(A) R (B) R/2 (C) R/3 (D) 2R

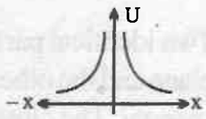
Q.28 An infinite nonconducting sheet of charge has a surface charge density of 10^{-7} C/m^2. The separation between two equipotential surfaces near the sheet whose potential differ by 5V is
(A) 0.88 cm (B) 0.88 mm (C) 0.88 m (D) 5×10^{-7} m

Q.29 Four equal charges +q are placed at four corners of a square with its centre at origin and lying in yz plane. The electrostatic potential energy of a fifth charge +q' varies on x-axis as:

(A) 

(B) 

(C) 

(D) 

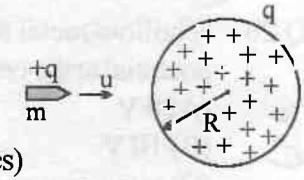
Q.30 Two identical thin rings, each of radius R meter are coaxially placed at distance R meter apart. If Q_1 and Q_2 coulomb are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is
(A) zero
(B) $q(Q_1-Q_2)(\sqrt{2}-1)/(\sqrt{2}.4\pi\varepsilon_0 R)$
(C) $q\sqrt{2}(Q_1+Q_2)/4\pi\varepsilon_0 R$
(D) $q(Q_1-Q_2)(\sqrt{2}+1)/(\sqrt{2}.4\pi\varepsilon_0 R)$

Q.31 Two positively charged particles X and Y are initially far away from each other and at rest. X begins to move towards Y with some initial velocity. The total momentum and energy of the system are p and E.
(A) If Y is fixed, both p and E are conserved.
(B) If Y is fixed, E is conserved, but not p.
(C) If both are free to move, p is conserved but not E.
(D) If both are free, E is conserved, but not p.

Q.33 Two particles X and Y, of equal mass and with unequal positive charges, are free to move and are initially far away from each other. With Y at rest, X begins to move towards it with initial velocity u. After a long time, finally
(A) X will stop, Y will move with velocity u.
(B) X and Y will both move with velocities u/2 each.
(C) X will stop, Y will move with velocity < u.
(D) both will move with velocities < u/2.

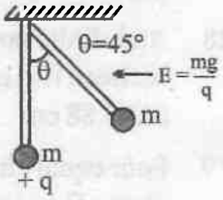
Q.34 A circular ring of radius R with uniform positive charge density λ per unit length is located in the y-z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point P($R\sqrt{3}$, O, O) on the positive x-axis directly towards O, with an initial kinetic energy $\frac{\lambda q}{4\varepsilon_0}$.
(A) The particle crosses O and goes to infinity.
(B) The particle returns to P.
(C) The particle will just reach O.
(D) The particle crosses O and goes to $-R\sqrt{3}$.

Q.35 A bullet of mass m and charge q is fired towards a solid uniformly charged sphere of radius R and total charge + q. If it strikes the surface of sphere with speed u, find the minimum speed u so that it can penetrate through the sphere. (Neglect all resistance forces or friction acting on bullet except electrostatic forces)



(A) $\frac{q}{\sqrt{2\pi\varepsilon_0 mR}}$ (B) $\frac{q}{\sqrt{4\pi\varepsilon_0 mR}}$ (C) $\frac{q}{\sqrt{8\pi\varepsilon_0 mR}}$ (D) $\frac{\sqrt{3}q}{\sqrt{4\pi\varepsilon_0 mR}}$

Q.36 In space of horizontal EF (E = (mg)/q) exist as shown in figure and a mass m attached at the end of a light rod. If mass m is released from the position shown in figure find the angular velocity of the rod when it passes through the bottom most position

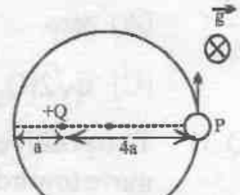


(A) $\sqrt{\frac{g}{l}}$ (B) $\sqrt{\frac{2g}{l}}$ (C) $\sqrt{\frac{3g}{l}}$ (D) $\sqrt{\frac{5g}{l}}$

Q.37 Two identical particles of mass m carry a charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards first particle from a large distance with speed v. The closed distance of approach be

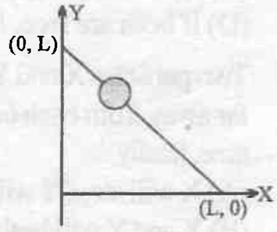
(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mv}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{4Q^2}{mv^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{2Q^2}{mv^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{mv^2}$

Q.38 The diagram shows a small bead of mass m carrying charge q. The bead can freely move on the smooth fixed ring placed on a smooth horizontal plane. In the same plane a charge +Q has also been fixed as shown. The potential atthe point P due to +Q is V. The velocity with which the bead should projected from the point P so that it can complete a circle should be greater than



(A) $\sqrt{\frac{6qV}{m}}$ (B) $\sqrt{\frac{qV}{m}}$ (C) $\sqrt{\frac{3qV}{m}}$ (D) none

Q.39 Electric field given by the vector $\vec{E} = x\hat{i} + y\hat{j}$ is present in the XY plane. A small ring carrying charge +Q, which can freely slide on a smooth non conducting rod, is projetced along the rod from the point (0, L) such that it can reach the other end of the rod. What minimum velocity should be given to the ring?(Assume zero gravity)



(A) $(QL^2/m)^{1/2}$ (B) $2(QL^2/m)^{1/2}$
(C) $4(QL^2/m)^{1/2}$ (D) $(QL^2/2m)^{1/2}$

Q.40 A unit positive point charge of mass m is projected with a velocity V inside the tunnel as shown. The tunnel has been made inside a uniformly charged non conducting sphere. The minimum velocity with which the point charge should be projected such it can it reach the opposite end of the tunnel, is equal to

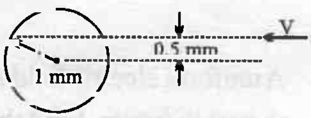


(A) $[\rho R^2/4m\varepsilon_0]^{1/2}$
(B) $[\rho R^2/24m\varepsilon_0]^{1/2}$
(C) $[\rho R^2/6m\varepsilon_0]^{1/2}$
(D) zero because the initial and the final points are at same potential.

Q.41 A conducting sphere of radius a has charge Q on it. It is enclosed by a neutral conducting concentric spherical shell having inner radius 2a and outer radius 3a. Find electrostatic energy of system.

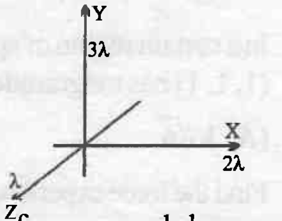
(A) $\frac{5}{12}\frac{kQ^2}{a}$ (B) $\frac{11}{12}\frac{kQ^2}{a}$ (C) $\frac{kQ^2}{2a}$ (D) none

Q.42 A particle of mass 1 kg & charge $\frac{1}{3}$ μC is projected towards a non conducting fixed spherical shell having the same charge uniformly distributed on its surface. Find the minimum initial velocity of projection required if the particle just grazes the shell.



(A) $\sqrt{\frac{2}{3}}$ m/s (B) $2\sqrt{\frac{2}{3}}$ m/s (C) $\frac{2}{3}$ m/s (D) none of these

Q.43 The diagram shows three infinitely long uniform line charges placed on the X, Y and Z axis. The work done in moving a unit positive charge from (1, 1, 1) to (0, 1, 1) is equal to



(A) $(\lambda \ln 2) / 2\pi\varepsilon_0$ (B) $(\lambda \ln 2) / \pi\varepsilon_0$
(C) $(3\lambda \ln 2) / 2\pi\varepsilon_0$ (D) None

Q.44 A charged particle of charge Q is held fixed and another charged particle of mass m and charge q (of the same sign) is released from a distance r. The impulse of the force exerted by the external agent on the fixed charge by the time distance between Q and q becomes 2r is

(A) $\sqrt{\frac{Qq}{4\pi\epsilon_0 mr}}$ (B) $\sqrt{\frac{Qqm}{4\pi\epsilon_0 r}}$ (C) $\sqrt{\frac{Qqm}{\pi\epsilon_0 r}}$ (D) $\sqrt{\frac{Qqm}{2\pi\epsilon_0 r}}$

Q.45 In a uniform electric field, the potential is 10V at the origin of coordinates, and 8V at each of the points (1, 0, 0), (0, 1, 0) and (0, 0, 1). The potential at the point (1, 1, 1) will be
(A) 0 (B) 4 V (C) 8 V (D) 10 V

Q.46 In a regular polygon of n sides, each corner is at a distance r from the centre. Identical charges are placed at (n – 1) corners. At the centre, the intensity is E and the potential is V. The ratio V/E has magnitude.
(A) r n (B) r (n – 1) (C) (n – 1)/r (D) r(n – 1)/n

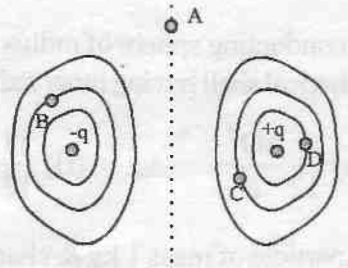
Q.47 The equation of an equipotential line in an electric field is y = 2x, then the electric field strength vector at (1, 2) may be
(A) $4\hat{i}+3\hat{j}$ (B) $4\hat{i}+8\hat{j}$ (C) $8\hat{i}+4\hat{j}$ (D) $-8\hat{i}+4\hat{j}$

Q.48 The electric field in a region is given by : $E = \left(4axy\sqrt{z}\right)\hat{i} + \left(2ax^2\sqrt{z}\right)\hat{j} + \left(ax^2/\sqrt{z}\right)\hat{k}$, where a is a positive constant. The equation of an equipotential surface will be of the form
(A) z = constant / $[x^3y^2]$ (B) z = constant / $[xy^2]$
(C) z = constant / $[x^4y^2]$ (D) None

Q.49 A charge 3 coulomb experiences a force 3000 N when placed in a uniform electric field. The potential difference between two points separated by a distance of 1 cm along the field lines is
(A) 10 V (B) 90 V (C) 1000 V (D) 9000V

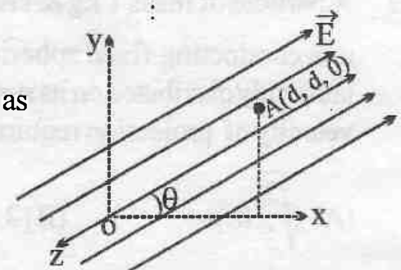
Q.50 Two point charges of +Q each have been placed at the positions (–a/2, 0, 0) and (a/2, 0, 0). The locus of the points where –Q charge can be placed such the that total electrostatic potential energy of the system can become equal to zero, is represented by which of the following equations?
(A) $Z^2 + (Y-a)^2 = 2a$ (B) $Z^2 + (Y-a)^2 = 27a^2/4$
(C) $Z^2 + Y^2 = 15a^2/4$ (D) None

Q.51 Figure shows equi-potential surfaces for a two charges system. At which of the labeled points point will an electron have the highest potential energy?



(A) Point A (B) Point B
(C) Point C (D) Point D

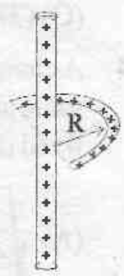
Q.52 A uniform electric field having strength $\vec{E}$ is existing in x-y plane as shown in figure. Find the p.d. between origin O & A(d, d, 0)



(A) Ed (cosθ + sinθ) (B) –Ed (sinθ – cosθ)
(C) $\sqrt{2}$ Ed (D) none of these

Q.53 In a certain region of space, the potential is given by : $V = k[2x^2 - y^2 + z^2]$. The electric field at the point (1, 1, 1) has magnitude =
(A) $k\sqrt{6}$ (B) $2k\sqrt{6}$ (C) $2k\sqrt{3}$ (D) $4k\sqrt{3}$

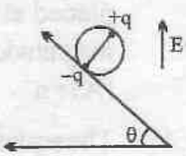
Q.54 Find the force experienced by the semicircular rod charged with a charge q, placed as shown in figure. Radius of the wire is R and the line of charge with linear charge density λ is passing through its centre and perpendicular to the plane of wire.



(A) $\frac{\lambda q}{2\pi^2\varepsilon_0 R}$ (B) $\frac{\lambda q}{\pi^2\varepsilon_0 R}$ (C) $\frac{\lambda q}{4\pi^2\varepsilon_0 R}$ (D) $\frac{\lambda q}{4\pi\varepsilon_0 R}$

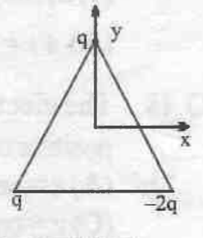
Q.55 Uniform electric field of magnitude 100 V/m in space is directed along the line y = 3 + x. Find the potential difference between point A (3, 1) & B (1, 3)
(A) 100 V (B) $200\sqrt{2}$ V (C) 200 V (D) 0

Q.56 A wheel having mass m has charges +q and –q on diametrically opposite points. It remains in equilibrium on a rough inclined plane in the presence of uniform vertical electric field E =



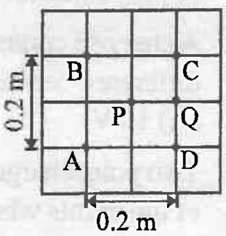
(A) $\frac{mg}{q}$ (B) $\frac{mg}{2q}$ (C) $\frac{mg\tan\theta}{2q}$ (D) none

Q.57 An equilateral triangle wire frame of side L having 3 point charges at its vertices is kept in x-y plane as shown. Component of electric field due to the configuration in z direction at (0, 0, L) is [origin is centroid of triangle]



(A) $\frac{9\sqrt{3}\,kq}{8L^2}$ (B) zero (C) $\frac{9kq}{8L^2}$ (D) None

Q.58 A, B, C, D, P and Q are points in a uniform electric field. The potentials a these points are V (A) = 2 volt. V (P) = V (B) = V (D) = 5 volt. V (C) = 8 volt. The electric field at P is



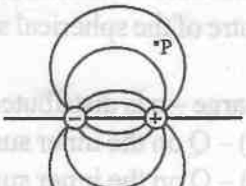
(A) 10 Vm^{-1} along PQ (B) $15\sqrt{2}$ V m^{-1} along PA
(C) 5 V m^{-1} along PC (D) 5 V m^{-1} along PA

Q.59 A and B are two points on the axis and the perpendicular bisector respectively of an electric dipole. A and B are far away from the dipole and at equal distance from it. The field at A and B are $\vec{E}_A$ and $\vec{E}_B$.

(A) $\vec{E}_A = \vec{E}_B$ (B) $\vec{E}_A = 2\vec{E}_B$

(C) $\vec{E}_A = -2\vec{E}_B$ (D) $|\vec{E}_B| = \frac{1}{2}|\vec{E}_A|$, and $\vec{E}_B$ is perpendicular to $\vec{E}_A$

Q.60 Figure shows the electric field lines around an electric dipole. Which of the arrows best represents the electric field at point P ?



(A) ↑ (B) ↖

(C) ↗ (D) ↙

Q.61 A dipole consists of two particles one with charge $+1\,\mu C$ and mass 1kg and the other with charge $-1\,\mu C$ and mass 2kg separated by a distance of 3m. For small oscillations about its equilibrium position, the angular frequency, when placed in a uniform electric field of 20kV/m is

(A) 0.1rad/s (B) 1.1 rad/s (C) 10 rad/s (D) 2.5rad/s

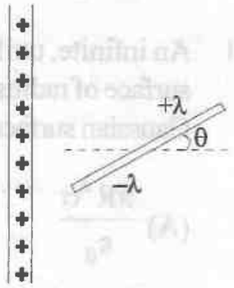
Q.62 The dipole moment of a system of charge +q distributed uniformly on an arc of radius R subtending an angle $\pi/2$ at its centre where another charge -q is placed is :

(A) $\frac{2\sqrt{2}qR}{\pi}$ (B) $\frac{\sqrt{2}qR}{\pi}$ (C) $\frac{qR}{\pi}$ (D) $\frac{2qR}{\pi}$

Q.63 An electric dipole is kept on the axis of a uniformly charged ring at distance $R/\sqrt{2}$ from the centre of the ring. The direction of the dipole moment is along the axis. The dipole moment is P, charge of the ring is Q and radius of the ring is R. The force on the dipole is nearly

(A) $\frac{4kPQ}{3\sqrt{3}R^2}$ (B) $\frac{4kPQ}{3\sqrt{3}R^3}$ (C) $\frac{2kPQ}{3\sqrt{3}R^3}$ (D) zero

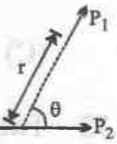
Q.64 A large sheet carries uniform surface charge density σ. A rod of length $2l$ has a linear charge density λ on one half and $-\lambda$ on the second half. The rod is hinged at mid point O and makes an angle θ with the normal to the sheet. The torque experienced by the rod is



(A) 0 (B) $\frac{\sigma\lambda l^2}{2\varepsilon_0}\sin\theta$

(C) $\frac{\sigma\lambda l^2}{\varepsilon_0}\sin\theta$ (D) $\frac{\sigma\lambda l}{2\varepsilon_0}$

Q.65 Two short electric dipoles are placed as shown. The energy of electric interaction between these dipoles will be

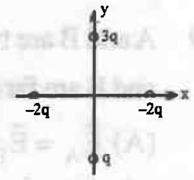


(A) $\frac{2kP_1P_2\cos\theta}{r^3}$ (B) $\frac{-2kP_1P_2\cos\theta}{r^3}$ (C) $\frac{-2kP_1P_2\sin\theta}{r^3}$ (D) $\frac{-4kP_1P_2\cos\theta}{r^3}$

Q.66 Point P lies on the axis of a dipole. If the dipole is rotated by 90° anticlock wise, the electric field vector $\vec{E}$ at P will rotate by

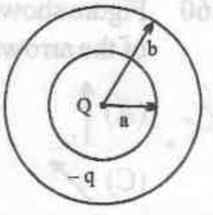
(A) 90° clock wise (B) 180° clock wise (C) 90° anti clock wise (D) none

Q.67 4 charges are placed each at a distance 'a' from origin. The dipole moment of configuration is



(A) 2qaj (B) 3qaj (C) $2aq[\hat{i}+\hat{j}]$ (D) none

Q.68 Both question (a) and (b) refer to the system of charges as shown in the figure. A spherical shell with an inner radius 'a' and an outer radius 'b' is made of conducting material. A point charge +Q is placed at the centre of the spherical shell and a total charge – q is placed on the shell.



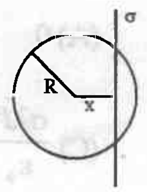
(a) Charge – q is distributed on the surfaces as
(A) – Q on the inner surface, – q on outer surface
(B) – Q on the inner surface, – q + Q on the outer surface
(C) +Q on the inner surface, –q – Q on the outer surface
(D) The charge –q is spread uniformly between the inner and outer surface.

(b) Assume that the electrostatic potential is zero at an infinite distance from the spherical shell. The electrostatic potential at a distance R (a < R < b) from the centre of the shell is
(A) 0 (B) $\frac{KQ}{a}$ (B) $K\frac{Q-q}{R}$ (D) $K\frac{Q-q}{b}$
(where $K = \frac{1}{4\pi\varepsilon_0}$)

Q.69 In a region of space, the electric field is in the x direction and is given as $\vec{E} = E_0 x\hat{i}$. Consider an imaginary cubical volume of edge a, with its edges parallel to the axes of coordinates. The charge inside this volume is:
(A) zero (B) $\varepsilon_0 E_0 a^3$ (C) $\frac{1}{\varepsilon_0}E_0 a^3$ (D) $\frac{1}{6}\varepsilon_0 E_0 a^2$

Q.70 Electric flux through a surface of area 100 m^2 lying in the xy plane is (in V-m) if $\vec{E} = \hat{i}+\sqrt{2}\hat{j}+\sqrt{3}k$
(A) 100 (B) 141.4 (C) 173.2 (D) 200

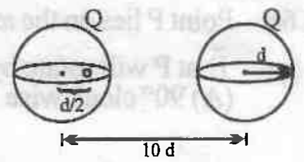
Q.71 An infinite, uniformly charged sheet with surface charge density σ cuts through a spherical Gaussian surface of radius R at a distance x from its center, as shown in the figure. The electric flux Φ through the Gaussian surface is



(A) $\frac{\pi R^2\sigma}{\varepsilon_0}$ (B) $\frac{2\pi(R^2-x^2)\sigma}{\varepsilon_0}$

(C) $\frac{\pi(R-x)^2\sigma}{\varepsilon_0}$ (D) $\frac{\pi(R^2-x^2)\sigma}{\varepsilon_0}$

Q.72 Two spherical, nonconducting, and very thin shells of uniformly distributed positive charge Q and radius d are located a distance 10d from each other. A positive point charge q is placed inside one of the shells at a distance d/2 from the center, on the line connecting the centers of the two shells, as shown in the figure. What is the net force on the charge q?



(A) $\frac{qQ}{361\pi\varepsilon_0 d^2}$ to the left (B) $\frac{qQ}{361\pi\varepsilon_0 d^2}$ to the right

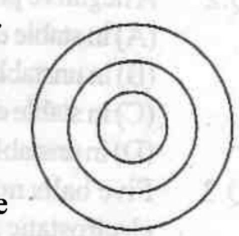
(C) $\frac{362qQ}{361\pi\varepsilon_0 d^2}$ to the left (D) $\frac{360qQ}{361\pi\varepsilon_0 d^2}$ to the right

Q.73 A positive charge q is placed in a spherical cavity made in a positively charged sphere. The centres of sphere and cavity are displaced by a small distance $\vec{l}$. Force on charge q is :
(A) in the direction parallel to vector $\vec{l}$
(B) in radial direction
(C) in a direction which depends on the magnitude of charge density in sphere
(D) direction can not be determined.

Q.74 There are four concentric shells A, B, C and D of radii a, 2a, 3a and 4a respectively. Shells B and D are given charges +q and –q respectively. Shell C is now earthed. The potential difference $V_A - V_C$ is :

(A) $\frac{Kq}{2a}$ (B) $\frac{Kq}{3a}$ (C) $\frac{Kq}{4a}$ (D) $\frac{Kq}{6a}$

Q.75 A metal ball of radius R is placed concentrically inside a hollow metal sphere of inner radius 2R and outer radius 3R. The ball is given a charge +2Q and the hollow sphere a total charge – Q. The electrostatic potential energy of this system is :



(A) $\frac{7Q^2}{24\pi\varepsilon_0 R}$ (B) $\frac{5Q^2}{16\pi\varepsilon_0 R}$ (C) $\frac{5Q^2}{8\pi\varepsilon_0 R}$ (D) None

Question No. 76 to 80

A point charge +Q having mass m is fixed on horizontal smooth surface. Another point charge having magnitude +2Q & mass 2m is projected horizontally towards the charge +Q from far distance with velocity V_o.

Q.76 Force applied by floor on the fixed charge in horizontal direction, when distance between charges becomes 'd'.

(A) $\frac{2KQ^2}{d^2}$ (B) $\frac{KQ^2}{d^2}$ (C) Zero (D) None

Q.77 The impulse acting on the system of particles (Q + 2Q) in the time interval when distance between them becomes 'd'.

(A) $2m\left[\sqrt{V_o^2 - \frac{2KQ^2}{md}} - V_o\right]$ (B) $2m\,V_0$

(C) $2m\left[\sqrt{V_o^2 - \frac{2KQ^2}{md}}\right]$ (D) None

Q.78 Minimum distance of approach.

(A) $\frac{2KQ^2}{mV_o^2}$ (B) $\frac{KQ^2}{mV_o^2}$ (D) $\frac{4KQ^2}{mV_o^2}$ (D) None

Q.79 Acceleration of particle 2Q when it is closest to fixed particle Q

(A) Zero (B) $\frac{mV_o^4}{2KQ^2}$ (C) $\frac{mV_o^4}{4KQ^2}$ (D) None

Q.80 If particle +Q is free to move, then what will be the closest distance between the particles.

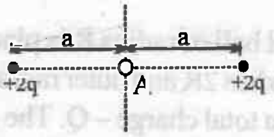
(A) Zero (B) $\frac{6KQ^2}{mV_o^2}$ (C) $\frac{3KQ^2}{mV_o^2}$ (D) None

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 Mid way between the two equal and similar charges, we placed the third equal and similar charge. Which of the following statements is correct, concerned to the equilibrium along the line joining the charges ?
(A) The third charge experienced a net force inclined to the line joining the charges
(B) The third charge is in stable equilibrium
(C) The third charge is in unstable equilibrium
(D) The third charge experiences a net force perpendicular to the line joining the charges

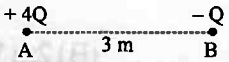
Q.2 A negative point charge placed at the point A is
(A) in stable equilibrium along x-axis
(B) in unstable equilibrium along y-axis
(C) in stable equilibrium along y-axis
(D) in unstable equilibrium along x-axis



Q.3 Five balls numbered 1 to 5 are suspended using separate threads. Pairs (1,2), (2,4) and (4,1) show electrostatic attraction while pairs (2,3) and (4,5) show repulsion. Therefore ball 1 must be
(A) positively charged (B) negatively charged (C) neutral (D) made of metal

Q.4 Four charges of 1 μC, 2 μC, 3 μC, and – 6μC are placed one at each corner of the square of side 1m. The square lies in the x-y plane with its centre at the origin.
(A) The electric potential is zero at the origin.
(B) The electric potential is zero everywhere along the x-axis only if the sides of the square are parallel to x and y axis.
(C) The electric potential is zero everywhere along the z-axis for any orientation of the square in the x-y plane.
(D) The electric potential is not zero along the z-axis except at the origin.

Q.5 Two fixed charges 4Q (positive) and Q (negative) are located at A and B, the distance AB being 3 m.

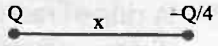


(A) The point P where the resultant field due to both is zero is on AB outside AB.
(B) The point P where the resultant field due to both is zero is on AB inside AB.
(C) If a positive charge is placed at P and displaced slightly along AB it will execute oscillations.
(D) If a negative charge is placed at P and displaced slightly along AB it will execute oscillations.

Q.6 Two identical charges +Q are kept fixed some distance apart. A small particle P with charge q is placed midway between them. If P is given a small displacement Δ, it will undergo simple harmonic motion if
(A) q is positive and Δ is along the line joining the charges.
(B) q is positive and Δ is perpendicular to the line joining the charges.
(C) q is negative and Δ is perpendicular to the line joining the charges.
(D) q is negative and Δ is along the line joining the charges.

Q.7 Select the correct statement : (Only force on a particle is due to electric field)
(A) A charged particle always moves along the electric line of force.
(B) A charged particle may move along the line of force
(C) A charge particle never moves along the line of force
(D) A charged particle moves along the line of force only if released from rest.

Q.8 Two point charges Q and – Q/4 are separated by a distance x. Then



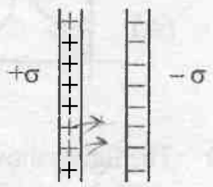
(A) potential is zero at a point on the axis which is x/3 on the right side of the charge – Q/4
(B) potential is zero at a point on the axis which is x/5 on the left side of the charge – Q/4
(C) electric field is zero at a point on the axis which is at a distance x on the right side of the charge – Q/4
(D) there exist two points on the axis where electric field is zero.

Q.9 An electric charge 10^{-8} C is placed at the point (4m, 7m, 2m). At the point (1m, 3m, 2m), the electric
(A) potential will be 18 V
(B) field has no Y-component
(C) field will be along Z-axis
(D) potential will be 1.8 V

Q.10 Let V be electric potential and E the magnitude of the electric field. At a given position, which of the statement is true?
(A) E is always zero where V is zero
(B) V is always zero where E is zero
(C) E can be zero where V is non zero
(D) E is always nonzero where V is nonzero

Q.11 Three point charges Q, 4Q and 16Q are placed on a straight line 9 cm long. Charges are placed in such a way that the system has minimum potential energy. Then
(A) 4Q and 16Q must be at the ends and Q at a distance of 3 cm from the 16Q.
(B) 4Q and 16Q must be at the ends and Q at a distance of 6 cm from the 16Q.
(C) Electric field at the position of Q is zero.
(D) Electric field at the position of Q is $\frac{Q}{4\pi\varepsilon_0}$.

Q.12 Two infinite sheets of uniform charge density $+\sigma$ and $-\sigma$ are parallel to each other as shown in the figure. Electric field at the



(A) points to the left or to the right of the sheets is zero.
(B) midpoint between the sheets is zero.
(C) midpoint of the sheets is σ / ε_0 and is directed towards right.
(D) midpoint of the sheet is $2\sigma / \varepsilon_0$ and is directed towards right.

Q.13 The electric potential decreases uniformly from V to -V along X-axis in a coordinate system as we moves from a point $(-x_0, 0)$ to $(x_0, 0)$, then the electric field at the origin.
(A) must be equal to $\frac{V}{x_0}$;
(B) may be equal to $\frac{V}{x_0}$
(C) must be greater than $\frac{V}{x_0}$
(D) may be less than $\frac{V}{x_0}$

Q.14 The electric potential decreases uniformly from 120 V to 80 V as one moves on the X–axis from x = –1 cm to x = + 1 cm. The electric field at the origin
(A) must be equal to 20 V/cm
(B) may be equal to 20 V/cm
(C) may be greater than 20 V/cm
(D) may be less than 20 V/cm

Q.15 Potential at a point A is 3 volt and at a point B is 7 volt, an electron is moving towards A from B.
(A) It must have some K.E. at B to reach A
(B) It need not have any K.E. at B to reach A
(C) to reach A it must have more than or equal to 4 eV K. E. at B.
(D) when it will reach A, it will have K.E. more then or at least equal to 4 eV if it was released from rest at B.

Q.16 A ring of radius R carries charge Q distributed uniformly over the ring. P is a point on its axis, at a distance r from its centre. The electric field at P due to ring is E. Which of the following is correct?

(A) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qr}{(r^2+R^2)^{3/2}}$.

(B) E is maximum for $r = R/\sqrt{2}$

(C) $E \neq 0$ at the centre of the ring.

(D) As r increases, E will first increase, then decrease.

Q.17 A conducting sphere of radius r has a charge. Then

(A) The charge is uniformly distributed over its surface, if there is an external electric field.

(B) Distribution of charge over its surface will be non uniform if no external electric field exist in space.

(C) Electric field strength inside the sphere will be equal to zero only when no external electric field exists

(D) Potential at every point of the sphere must be same

Q.18 For a spherical shell

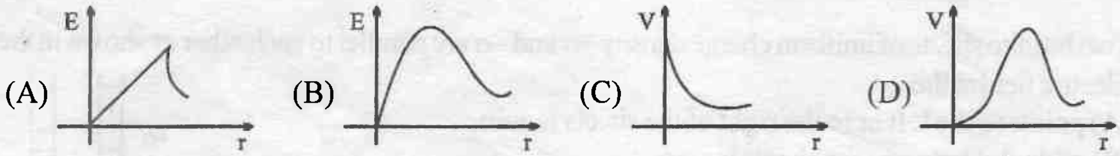
(A) If potential inside it is zero then it necessarily electrically neutral

(B) electric field in a charged conducting spherical shell can be zero only when the charge is uniformly distributed.

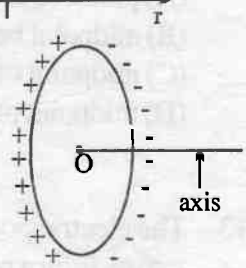
(C) electric potential due to induced charges at a point inside it will always be zero

(D) none of these

Q.19 A circular ring carries a uniformly distributed positive charge. The electric field (E) and potential (V) varies with distance (r) from the centre of the ring along its axis as



Q.20 The figure shows a nonconducting ring which has positive and negative charge non uniformly distributed on it such that the total charge is zero. Which of the following statements is true?



(A) The potential at all the points on the axis will be zero.

(B) The electric field at all the points on the axis will be zero.

(C) The direction of electric field at all points on the axis will be along the axis.

(D) If the ring is placed inside a uniform external electric field then net torque and force acting on the ring would be zero.

Q.21 At distance of 5cm and 10cm outwards from the surface of a uniformly charged solid sphere, the potentials are 100V and 75V respectively. Then

(A) potential at its surface is 150V.

(B) the charge on the sphere is $(5/3) \times 10^{-10}$C.

(C) the electric field on the surface is 1500 V/m.

(D) the electric potential at its centre is 225V.

Q.22 Four identical charges are placed at the points (1, 0, 0), (0, 1, 0), (–1, 0, 0) and (0, –1, 0).

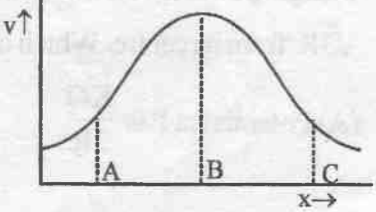
(A) The potential at the origin is zero.

(B) The field at the origin is zero.

(C) The potential at all points on the z-axis, other than the origin, is zero.

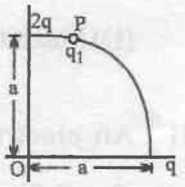
(D) The field at all points on the z-axis, other than the origin acts along the z-axis.

Q.23 Variation of electrostatic potential along x-direction is shown in the graph. The correct statement about electric field is
(A) x component at point B is maximum
(B) x component at point A is towards positive x-axis.
(C) x component at point C is along negative x-axis
(D) x component at point C is along positive x-axis



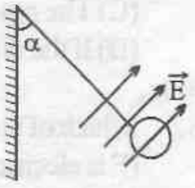
Q.24 A particle of charge 1 μC & mass 1 gm moving with a velocity of 4 m/s is subjected to a uniform electric field of magnitude 300 V/m for 10 sec. Then it's final speed cannot be:
(A) 0.5 m/s (B) 4 m/s (C) 3 m/s (D) 6 m/s

Q.25 Two point charges q and 2q are placed at (a, 0) and (0, a). A point charge q_1 is placed at a point P on the quarter circle of radius a as shown in the diagram so that the electric field at the origin becomes zero:



(A) the point P is $\left(\frac{a}{\sqrt{3}}, \frac{\sqrt{2}a}{\sqrt{3}}\right)$ (B) the point P is $\left(\frac{a}{\sqrt{5}}, \frac{2a}{\sqrt{5}}\right)$
(C) $q_1 = -5q$ (D) none of these

Q.26 A charged cork of mass m suspended by a light string is placed in uniform electric filed of strength $E = (\hat{i} + \hat{j}) \times 10^5\ NC^{-1}$ as shown in the fig. If in equilibrium position tension in the string is $\frac{2mg}{(1+\sqrt{3})}$ then angle 'α' with the vertical is
(A) 60° (B) 30° (C) 45° (D) 18°



Q.27 Two particles of same mass and charge are thrown in the same direction along the horizontal with same velocity v from two different heights h_1 and h_2 ($h_1 < h_2$). Initially they were located on the same vertical line. Choose the correct alternative.
(A) Both the particles will always lie on a vertical line.
(B) Acceleration of the centre of mass of two particles will be g downwards.
(C) Horizontal displacement of the particle lying at h_1 is less and the particle lying at h_2 is more than the value, which would had been in the absence of charges on them.
(D) all of these.

Q.28 A proton and a deuteron are initially at rest and are accelerated through the same potential difference. Which of the following is false concerning the final properties of the two particles ?
(A) They have different speeds (B) They have same momentum
(C) They have same kinetic energy (D) They have been subjected to same force

Q.29 A particle of charge – q and mass m moves in a circle around a long wire of linear charge density + λ. If r = radius of the circular path and T = time period of the motion circular path. Then :
(A) $T = 2\pi r\,(m/2K\lambda q)^{1/2}$ (B) $T^2 = 4\pi^2 m r^3/2qK\lambda$
(C) $T = 1/2\pi r\,(2K\lambda q/m)^{1/2}$ (D) $T = 1/2\pi r\,(m/K\pi\lambda q)^{1/2}$ where $K = 1/4\pi\epsilon_0$

Q.30 Charge Q is distributed non-uniformly over a ring of radius R, P is a point on the axis of ring at a distance $\sqrt{3}R$ from its centre. Which of the following is a wrong statement.

(A) Potential at P is $\frac{KQ}{2R}$

(B) Magnitude of electric field at P may be greater than $\frac{\sqrt{3}KQ}{8R^2}$

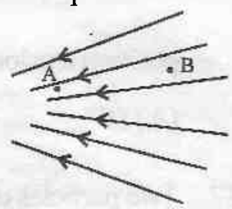
(C) Magnitude of electric field at P must be equal to $\frac{\sqrt{3}KQ}{8R^2}$

(D) Magnitude of electric field at P cannot be less than $\frac{\sqrt{3}KQ}{8R^2}$

Q.31 An electric dipole moment $\vec{p} = (2.0\hat{i} + 3.0\hat{j})\ \mu C.\ m$ is placed in a uniform electric field $\vec{E} = (3.0\hat{i} + 2.0\hat{k}) \times 10^5\ N\ C^{-1}$.

(A) The torque that $\vec{E}$ exerts on $\vec{p}$ is $(0.6\hat{i} - 0.4\hat{j} - 0.9\hat{k})$ Nm.
(B) The potential energy of the dipole is –0.6 J.
(C) The potential energy of the dipole is 0.6 J.
(D) If the dipole is rotated in the electric field, the maximum potential energy of the dipole is 1.3 J.

Q.32 Which of the following is true for the figure showing electric lines of force?
(E is electrical field, V is potential)



(A) $E_A > E_B$ (B) $E_B > E_A$
(C) $V_A > V_B$ (D) $V_B > V_A$

Q.33 If we use permittivity ε, resistance R, gravitational constant G and voltage V as fundamental physical quantities, then
(A) [angular displacement] = $\varepsilon^0 R^0 G^0 V^0$ (B) [Velocity] = $\varepsilon^{-1} R^{-1} G^0 V^0$
(C) [dipole moment] = $\varepsilon^1 R^0 G^0 V^1$ (D) [force] = $\varepsilon^1 R^0 G^0 V^2$

Q.34 Units of electric flux are

(A) $\frac{N - m^2}{Coul^2}$ (B) $\frac{N}{Coul^2 - m^2}$ (C) volt-m (D) Volt-m^3

Q.35 Which of the following statements are correct?
(A) Electric field calculated by Gauss law is the field due to only those charges which are enclosed inside the Gaussian surface.
(B) Gauss law is applicable only when there is a symmetrical distribution of charge.
(C) Electric flux through a closed surface will depends only on charges enclosed within that surface only.
(D) None of these

Q.36 Mark the correct options:
(A) Gauss's law is valid only for uniform charge distributions.
(B) Gauss's law is valid only for charges placed in vacuum.
(C) The electric field calculated by Gauss's law is the field due to all the charges .
(D) The flux of the electric field through a closed surface due to all the charges is equal to the flux due to the charges enclosed by the surface.

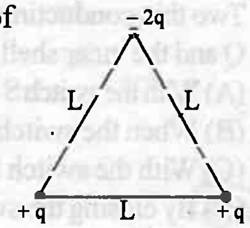
Q.37 A thin-walled, spherical conducting shell S of radius R is given charge Q. The same amount of charge is also placed at its centre C. Which of the following statements are correct?

(A) On the outer surface of S, the charge density is $\frac{Q}{2\pi R^2}$.
(B) The electric field is zero at all points inside S.
(C) At a point just outside S, the electric field is double the field at a point just inside S.
(D) At any point inside S, the electric field is inversely proportional to the square of its distance from C.

Q.38 A hollow closed conductor of irregular shape is given some charge. Which of the following statements are correct?
(A) The entire charge will appear on its outer surface.
(B) All points on the conductor will have the same potential.
(C) All points on its surface will have the same charge density.
(D) All points near its surface and outside it will have the same electric intensity.

Q.39 Charges Q_1 and Q_2 lies inside and outside respectively of a closed surface S. Let E be the field at any point on S and ϕ be the flux of E over S.
(A) If Q_1 changes, both E and ϕ will change.
(B) If Q_2 changes, E will change but ϕ will not change.
(C) If $Q_1 = 0$ and $q_2 \neq 0$ then $E \neq 0$ but $\phi = 0$.
(D) If $Q_1 \neq 0$ and $Q_2 = 0$ then $E = 0$ but $\phi \neq 0$.

Q.40 Three points charges are placed at the corners of an equilateral triangle of side L as shown in the figure.

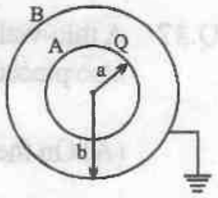


(A) The potential at the centroid of the triangle is zero.
(B) The electric field at the centroid of the triangle is zero.
(C) The dipole moment of the system is $\sqrt{2}\,qL$
(D) The dipole moment of the system is $\sqrt{3}\,qL$.

Q.41 An electric dipole is placed at the centre of a sphere. Mark the correct answer
(A) the flux of the electric field through the sphere is zero
(B) the electric field is zero at every point of the sphere.
(C) the electric potential is zero everywhere on the sphere.
(D) the electric potential is zero on a circle on the surface.

Q.42 An electric field converges at the origin whose magnitude is given by the expression E = 100rNt/Coul, where r is the distance measured from the origin.
(A) total charge contained in any spherical volume with its centre at origin is negative.
(B) total charge contained at any spherical volume, irrespective of the location of its centre, is negative.
(C) total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3×10^{-13}C.
(D) total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3×10^{-9} Coul.

Q.43 A conducting sphere A of radius a, with charge Q, is placed concentrically inside a conducting shell B of radius b. B is earthed. C is the common centre of the A and B.



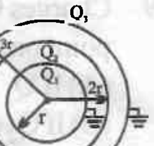
(A) The field is a distance r from C, where $a \le r \le b$ is $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$.

(B) The potential at a distance r from C, where $a < r < b$, is $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$.

(C) The potential difference between A and B is $\frac{1}{4\pi\varepsilon_0}Q\left(\frac{1}{a}-\frac{1}{b}\right)$

(D) The potential at a distance r from C, where $a \le r \le b$, $\frac{1}{4\pi\varepsilon_0}Q\left(\frac{1}{r}-\frac{1}{b}\right)$

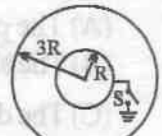
Q.44 Three concentric conducting spherical shells have radius r, 2r and 3r and Q_1, Q, and Q_3 are final charges respectively. Innermost and outermost shells are already earthed as shown in figure. Choose the wrong statement.



(A) $Q_1 + Q_3 = -Q_2$ (B) $Q_1 = \frac{-Q_2}{4}$

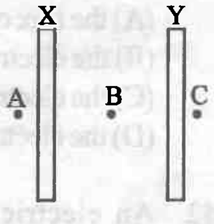
(C) $\frac{Q_3}{Q_1} = 3$ (D) $\frac{Q_3}{Q_2} = \frac{-1}{3}$

Q.45 Two thin conducting shells of radii R and 3R are shown in the figure. The outer shell carries a charge +Q and the inner shell is neutral. The inner shell is earthed with the help of a switch S.



(A) With the switch S open, the potential of the inner sphere is equal to that of the outer.
(B) When the switch S is closed, the potential of the inner sphere becomes zero.
(C) With the switch S closed, the charge attained by the inner sphere is – q/3.
(D) By closing the switch the capacitance of the system increases.

Q.46 X and Y are large, parallel conducting plates closed to each other. Each face has an area A. X is given a charge Q. Y is without any charge. Points A, B and C are as shown in figure.

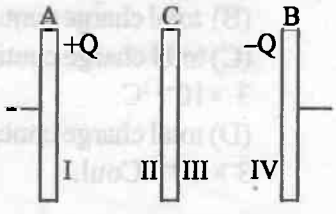


(A) The field at B is $\frac{Q}{2\varepsilon_0 A}$

(B) The field at B is $\frac{Q}{\varepsilon_0 A}$

(C) The fields at A, B and C are of the same magnitude.
(D) The field at A and C are of the same magnitude, but in opposite directions.

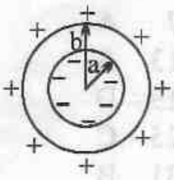
Q.47 Plates A and B constitute an isolated, charge parallel-plate capacitor. The inner surfaces (I and IV) of A and B have charges +Q and –Q respectively. A third plate C with charge +Q is now introduced midway between A and B. Which of the following statements is not correct?



(A) The surfaces I and II will have equal and opposite charges.
(B) The surfaces III and IV will have equal and opposite charges.
(C) the charge on surface III will be greater than Q.
(D) The potential difference between A and C will be equal to the potential difference between C and B.

Q.48 A particle of mass m and charge q is thrown in a region where uniform gravitational field and electric field are present. The path of particle
(A) may be a straight line (B) may be a circle
(C) may be a parabola (D) may be a hyperbola

Question No. 49 to 54 (6 questions)
An empty thick conducting shell of inner radius a and outer radius b is shown in figure. If it is observed that the inner face of the shell carries a uniform charge density $-\sigma$ and the surface carries a uniform charge density 'σ'



Q.49 If a point charge q_A is placed at the center of the shell, then choose the correct statement(s)
(A) The charge must be positive
(B) The charge must be negative
(C) The magnitude of charge must be $4\pi\sigma a^2$
(D) The magnitude of charge must be $4\pi\sigma(b^2 - a^2)$

Q.50 If another point charge q_B is also placed at a distance c (>b) the center of shell, then choose the correct statements
(A) force experienced by charge A is $\frac{\sigma q_A b^2}{\varepsilon_0 c^2}$
(B) force experienced by charge A is zero
(C) The force experienced by charge B is $\frac{\sigma q_B b^2}{\varepsilon_0 c^2}$
(D) The force experienced by charge B is $\frac{kq_A q_B}{c^2}$

Q.51 If the charge q_A is slowly moved inside the shell, then choose the statement(s)
(A) Charge distribution on the inner and outer face of the shell changes
(B) The force acting on the charge B charges
(C) The charge B also starts moving slowly
(D) None of these

Q.52 Choose the correct statement related to the potential of the shell in absence of q_B
(A) Potential of the outer surface is more than that of the inner surface because it is positively charged
(B) Potential of the outer surface is more than that of the inner surface because it carries more charge
(C) Both the surfaces have equal potential
(D) The potential of the outer surface is $\frac{\sigma b}{\varepsilon_0}$

Q.53 If the outer surface of the shell is earthed, then identify the correct statement(s)
(A) Only the potential of outer surface becomes zero
(B) Charge on the outer surface also becomes zero
(C) The outer surface attains negative charge
(D) Negative charge on the inner surface decreases

Q.54 If the inner surface of the shell is earthed, then identify the correct statement(s)
(A) The potential of both the inner and outer surface of the shell becomes zero
(B) Charge on the outer surface becomes zero
(C) Charge on the inner surface decreases
(D) Positive charge flows from the shell to the earth

ANSWER KEY

ONLY ONE OPTION IS CORRECT.

Q.1	B	Q.2	D	Q.3	C	Q.4	D	Q.5	B	Q.6	D
Q.7	A	Q.8	D	Q.9	B	Q.10	D	Q.11	A	Q.12	A
Q.13	A	Q.14	D	Q.15	B	Q.16	A	Q.17	B	Q.18	D
Q.19	D	Q.20	A	Q.21	A	Q.22	C	Q.23	B	Q.24	D
Q.25	C	Q.26	B	Q.27	C	Q.28	B	Q.29	B	Q.30	B
Q.31	B	Q.33	A	Q.34	C	Q.35	B	Q.36	B	Q.37	B
Q.38	A	Q.39	D	Q.40	A	Q.41	A	Q.42	B	Q.43	B
Q.44	B	Q.45	B	Q.46	B	Q.47	D	Q.48	C	Q.49	A
Q.50	C	Q.51	B	Q.52	A	Q.53	B	Q.54	B	Q.55	D
Q.56	B	Q.57	B	Q.58	B	Q.59	C	Q.60	B	Q.61	A
Q.62	A	Q.63	D	Q.64	B	Q.65	B	Q.66	A	Q.67	A
Q.68	(a) B, (b) D	Q.69	B	Q.70	C	Q.71	D	Q.72	A	Q.73	A
Q.74	D	Q.75	A	Q.76	A	Q.77	A	Q.78	A	Q.79	C
Q.80	B										

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	B	Q.2	C, D	Q.3	C, D	Q.4	A, C
Q.5	A, D	Q.6	A, C	Q.7	B	Q.8	A, B, C
Q.9	A	Q.10	C	Q.11	B, C	Q.12	A, C
Q.13	B	Q.14	B, C	Q.15	A, C	Q.16	A, B, D
Q.17	D	Q.18	D	Q.19	B	Q.20	A
Q.21	A, C, D	Q.22	B, D	Q.23	D	Q.24	A
Q.25	B	Q.26	A, B	Q.27	D	Q.28	B
Q.29	A	Q.30	C	Q.31	A, B, D	Q.32	A, D
Q.33	A, B, D	Q.34	C	Q.35	C	Q.36	C, D
Q.37	A,C,D	Q.38	A,B	Q.39	A,B,C	Q.40	A,D
Q.41	A,D	Q.42	A,B,C	Q.43	A,C,D	Q.44	D
Q.45	A,B,C,D	Q.46	A,C,D	Q.47	D	Q.48	A,C
Q.49	A,C	Q.50	B	Q.51	D	Q.52	C,D
Q.53	B	Q.54	A,B,D				

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

ERROR IN MEASUREMENTS & INSTRUMENTS

ERRORS

Whenever an experiment is performed, two kinds of errors can appear in the measured quantity.

(1) indeterminate and (2) determinate (or systematic) errors.

1. Indeterminate errors appear randomly because of operator, fluctuations in external conditions and variability of measuring instruments. The effect of indeterminate error can be some what reduced by taking the average of measured values. Indeterminate errors have no fixed sign or size.
2. Determinate errors occur due to error in the procedure, or miscalibration of the intrument etc. Such errors have same size and sign for all the measurements. Such errors can be determined.

A measurement with relatively small indeterminate error is said to have high precision. A measurement with small indeterminate error and small determinate error is said to have high accuracy.

The experimental error [uncertainty] can be expressed in several standard ways.

Error limits $Q \pm \Delta Q$ is the measured quantity and ΔQ is the magnitude of its limit of error. This expresses the experimenter's judgment that the 'true' value of Q lies between $Q - \Delta Q$ and $Q + \Delta Q$. This entire interval within which the measurement lies is called the range of error. Indeterminate errors are expressed in this form.

Absolute Error

Error may be expressed as absolute measures, giving the size of the error in a quantity in the same units as the quantity itself.

Relative (or Fractional) Error

Error may be expressed as relative measures, giving the ratio of the quantity's error to the quantity itself. In general

$$\text{relative error} = \frac{\textit{absolute error in a measurement}}{\textit{size of the measurement}}$$

We should know the error in the measurement because these errors propagate through the calculations to produce errors in results.

A. ***Determinate errors*** **:** They have a known sign.

1. Suppose that a result R is calculated from the sum of two measured quantities A and B. We'll use a and b to represent the error in A and B respectively. r is the error in the result R. Then

$$(R + r) = (A + B) + (a + b)$$

The error in R is therefore : $r = a + b$.

Similarly, when two quantities are subtracted, the determinate errors also get subtracted.

2. Suppose that a result R is calculated by multiplying two measured quantities A and B. Then $R = AB$.

$(R + r) = (A + a)(B + b) = AB + aB + Ab + ab$

$\Rightarrow \quad \frac{r}{R} = \frac{aB + bA}{AB} = \frac{a}{A} + \frac{b}{B}$. Thus when two quantities are multiplied, their relative determinate error add.

3. **Quotient rule :** When two quantities are divided, the relative determinate error of the quotient is the relative determinate error of the numerator minus the relative determinate error of the denominator. Thus if $R = \frac{A}{B}$ then

$$\frac{r}{R} = \frac{a}{A} - \frac{b}{B}$$

4. **Power rule :** When a quantity Q is raised to a power, P, the relative determinate error in the result is P times the relative determinate error in Q.

If $R = Q^P$, $\quad \frac{r}{R} = P \times \frac{q}{Q}$

This also holds for negative powers,

5. The quotient rule is not applicable if the numerator and denominator are dependent on each other.

e.g if $R = \frac{XY}{X+Y}$ We cannot apply quotient rule to find the error in R. Instead we write the equation as follows

$\frac{1}{R} = \frac{1}{X} + \frac{1}{Y}$. Differentiating both the sides, we get

$$-\frac{dR}{R^2} = -\frac{dX}{X^2} - \frac{dY}{Y^2}. \qquad \text{Thus } \frac{r}{R^2} = \frac{x}{X^2} + \frac{y}{Y^2} \text{ or } \frac{r}{R} = \frac{R}{X} \times \frac{x}{X} + \frac{R}{Y} \times \frac{y}{Y}$$

B. ***Indeterminate error*** **:** They have unknown sign. Thus they are represented in the form $A \pm a$.

Here we are only concerned with *limits of error*. We must assume a "worst-case" combination. In the case of substraction, A – B, the worst-case deviation of the answer occurs when the errors are either + a and – b or – a and + b. In either case, the maximum error will be (a + b)

1. ***Addition and subtraction rule*** **:** The absolute indeterminate errors add.
   Thus if $R = A + B, \quad r = a + b$
   and if $R = A - B, \quad r = a + b$
2. ***Product and quotient rule*** **:** The relative indeterminate errors add.
   Thus if $R = AB, \quad \frac{r}{R} = \frac{a}{A} + \frac{b}{B}$
   and if $R = \frac{A}{B}$, then also $\frac{r}{R} = \frac{a}{A} + \frac{b}{B}$
3. ***Power rule*** **:** When a quantity Q is raised to a power P, the relative error in the result is P times the relative error in Q. This also holds for negative powers.
   If $R = Q^P, \frac{r}{R} = P \times \frac{q}{Q}$

Examples

1. A student finds the constant acceleration of a slowly moving object with a stopwatch. The equation used is $S = (1/2)AT^2$. The time is measured with a stopwatch, the distance, S with a meter stick. What is the acceleration and its estimated error?
   $S = 2 \pm 0.005$ meter.
   $T = 4.2 \pm 0.2$ second.

Sol : We use capital letters for quantities, lower case for errors. Solve the equation for the result, a.

$A = 2S/T^2$. Its indeterminate-error equation is $\frac{a}{A} = 2\frac{t}{T} + \frac{s}{S}$

Thus $A = 0.23 \pm 0.02$ m/s^2.

SIGNIFICANT DIGITS

Significant figures are digits that are statistically significant. There are two kinds of values in science :

1. Measured Values 2. Computed Values

The way that we identify the proper number of significant figures in science are different for these two types.

MEASURED VALUES

Identifying a measured value with the correct number of significant digits requires that the instrument's calibration be taken into consideration. The last significant digit in a measured value will be the first estimated position. For example, a metric ruler is calibrated with numbered calibrations equal to 1 cm. In addition, there will be ten unnumbered calibration marks between each numbered position. (each equal to 0.1 cm). Then one could with a little practice estimate between each of those marking. (each equal to 0.05 cm). That first estimated position would be the last significant digit reported in the measured value. Let's say that we were measuring the length of a tube, and it extended past the fourteenth numbered calibration half way between the third and fourth unnumbered mark. The metric ruler was a meter stick with 100 numbered calibrations. The reported measured length would be 14.35 cm. Here the total number of significant digits will be 4.

COMPUTED VALUE

The other type of value is a computed value. The proper number of significant figures that a computed value should have is decided by a set of conventional rules. However before we get to those rules for computed values we have to consider how to determine how many significant digits are indicated in the numbers being used in the math computation.

A. Rules for determining the number of significant digits in number with indicated decimals.

1. All non-zero digits (1-9) are to be counted as significant.
2. Zeros that have any non-zero digits anywhere to the LEFT of them are considered significant zeros.
3. All other zeros not covered in rule (ii) above are NOT be considered significant digits.

For example : 0.0040000

The 4 is obviously to be counted significant (Rule-1), but what about the zeros? The first three zeros would not be considered significant since they have no non-zero digits anywhere to their left (Rule-3). The last four zeros would all be considered significant since each of them has the non-zero digit 4 to their left (Rule-2). Therefore the number has a total of five significant digits.

Here is another example : 120.00420

The digit 1, 2, 4 and 2 are all considered significant (Rule-1). All zeros are considered significant since they have non-zero digits somewhere to their left (Rule-2). So there are a total of eight significant digits.

B. Determining the number of significant digits if number is not having an indicated decimal.

The decimal indicated in a number tells us to what position of estimation the number has been indicated. But what about 1,000,000?

Notice that there is no decimal indicated in the number. In other words, there is an ambiguity concerning the estimated position. This ambiguity can only be clarified by placing the number in exponential notation.

For example : If I write the number above in this manner.

$$1.00 \times 10^6$$

I have indicated that the number has been recorded with three significant digits. On the other hand, if I write the same number as : 1.0000×10^6

I have identified the number to have 5 significant digits. Once the number has been expressed in exponential notation form then the digits that appear before the power of ten will all be considered significant. So for example : 2.0040×10^4 will have five significant digits. This means that unit conversion will not change the number of significant digits. Thus 0.000010 km = 1.0 cm = 0.010 m = 1.0×10^{-2} m = 1.0×10^{-5} km

Rule for expressing proper number of significant digits in an answer from multiplication or division

For multiplication AND division there is the following rule for expressing a computed product or quotient with the proper number of significant digits.

The product or quotient will be reported as having as many significant digits as the number involved in the operation with the least number of significant digits.

For example : $0.000170 \times 100.40 = 0.017068$

The product could be expressed with no more that three significant digits since 0.000170 has only three significant digits, and 100.40 has five. So according to the rule the product answer could only be expressed with three significant digits. Thus the answer should be 0.0171 (after rounding off)

Another example : $2.000 \times 10^4 / 6.0 \times 10^{-3} = 0.33 \times 10^7$

The answer could be expressed with no more that two significant digits since the least digited number involved in the operation has two significant digits.

Sometimes this would required expressing the answer in exponential notation.

For example : $3.0 \times 800.0 = 2.4 \times 10^3$

The number 3.0 has two significant digits and then number 800.0 has four. The rule states that the answer can have no more than two digits expressed. However the answer as we can all see would be 2400. How do we express the answer 2400 while obeying the rules? The only way is to express the answer in exponential notation so 2400 could be expressed as : 2.4×10^3

Rule for expressing the correct number of significant digits in an addition or substraction :

The rule for expressing a sum or difference is considerably different than the one for multiplication of division. The sum or difference can be no more precise than the least precise number involved in the mathematical operation.Precision has to do with the number of positions to the RIGHT of the decimal. The more position to the right of the decimal, the more precise the number. So a sum or difference can have no more indicated positions to the right of the decimal as the number involved in the operation with the LEAST indicated positions to the right of its decimal.

For example : 160.45 + 6.732 = 167.18 (after rounding off)
The answer could be expressed only to two positions to the right of the decimal, since 160.45 is the least precise.
Another example : 45.621 + 4.3 – 6.41 = 43.5 (after rounding off)
The answer could be expressed only to one position to the right of the decimal, since the number 4.3 is the least precise number (i.e. having only one position to the right of its decimal). Notice we aren't really determining the total number of significant digits in the answer with this rule.

Rules for rounding off digits :

There are a set of conventional rules for rounding off.

1. Determine according to the rule what the last reported digit should be.
2. Consider the digit to the right of the last reported digit.
3. If the digit to the right of the last reported digit is less than 5 round it and all digits to its right off.
4. If the digit to the right of the last reported digit is greater than 5 round it and all digits to its right off and increased the last reported digit by one.
5. If the digit to the right of the last reported digit is a 5 followed by either no other digits or all zeros, round it and all digits to its right off and if the last reported digit is odd round up to the next even digit. If the last reported digit is even then leave it as is.

For example if we wish to round off the following number to 3 significant digits : 18.3682
The last reported digits would be the 3. The digit to its right is a 6 which is greater than 5. According to the Rule-4 above, the digit 3 is increased by one and the answer is : 18.4

Another example : Round off 4.565 to three significant digits.
The last reported digit would be the 6. The digit to the right is a 5 followed by nothing. Therefore according to Rule-5 above since the 6 is even it remains so and the answer would be 4.56.

EXPERIMENTS

(i) Measurement of length

The simplest method measuring the length of a straight line is by means of a meter scale. But there exists some limitation in the accuracy of the result:

(i) the dividing lines have a finite thickness.
(ii) naked eye cannot correctly estimate less than 0.5 mm

For greater accuracy devices like
(a) Vernier callipers (b) micrometer scales (screw gauge) are used.

VERNIER CALLIPERS:

It consists of a main scale graduated in cm/mm over which an auxiliary scale (or Vernier scale) can slide along the length. The division of the Vernier scale being either slightly longer and shorter than the divisions of the main scale.

Least count of Vernier Callipers

The least count or Vernier constant (v. c) is the minimum value of correct estimation of length without eye estimation. If N division of vernier coincides with (N-1) division of main scale, then

Vernier constant = 1 ms – 1 vs = $\left(1-\frac{N-1}{N}\right)$ ms = $\frac{1\text{ms}}{N}$, which is equal to the value of the smallest division on the main scale divided by total number of divisions on the vernier scale.

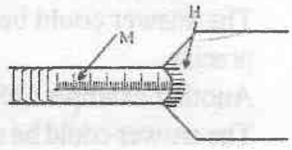
Zero error:

If the zero marking of main scale and vernier callipers do not coincide, necessary correction has to be made for this error which is known as zero error of the instrument.

If the zero of the vernier scale is to the right of the zero of the main scale the zero error is said to be positive and the correction will be negative and vice versa.

SCREW. GAUGE (OR MICROMETER SCREW)

In general vernier callipers can measure accurately upto 0.01 em and for greater accuracy micrometer screw devices e.g. screw gauge, spherometer are used. These consist of accurately cut screw which can be moved in a closely fitting fixed nut by turning it axially. The instrument is provided with two scales:



(i) The main scale or pitch scale M graduated along the axis of the screw.

(ii) The cap-scale or head scale H round the edge of the screw head.

Constants of the Screw Gauge

(a) **Pitch :** The translational motion of the screw is directly proportional to the total rotation of the head. The pitch of the instrument is the distance between two consecutive threads of the screw which is equal to the distance moved by the screw due to one complete rotation of the cap. Thus for 10 rotation of cap =5 mm. then pitch = 0.5 mm

(b) **Least count :** In this case also, the minimum (or least) measurement (or count) of length is equal to one division on the head scale which is equal to pitch divided by the total cap divisions. Thus in the aforesaid Illustration:, if the total cap division is 100, then least count = 0.5mm/100 = 0.005 mm

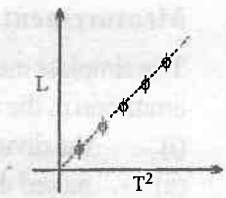
Zero Error : In a perfect instrument the zero of the heat scale coincides with the line of graduation along the screw axis with no zero-error, otherwise the instrument is said to have zero-error which is equal to the cap reading with the gap closed. This error is positive when zero line or reference line of the cap lies above the line of graduation and versa. The corresponding corrections will be just opposite.

(ii) **Measurement of g using a simple pendulum**

A small spherical bob is attached to a cotton thread and the combination is suspended from a point A. The length of the thread (L) is read off on a meter scale. A correction is added to L to include the finite size of the bob and the hook. The corrected value of L is used for further calculation. The bob is displaced slightly to one side and is allowed to oscillate, and the total time taken for 50 complete oscillations is noted on a stop-watch. The time period (T) of a single oscillation is now calculated by division.



Observations are now taken by using different lengths for the cotton thread (L) and pairs of values of L and T are taken. A plot of L v/s T^2, on a graph, is linear. g is given by $g = 4\pi^2 \dfrac{L}{T^2}$



The major errors in this experiment are

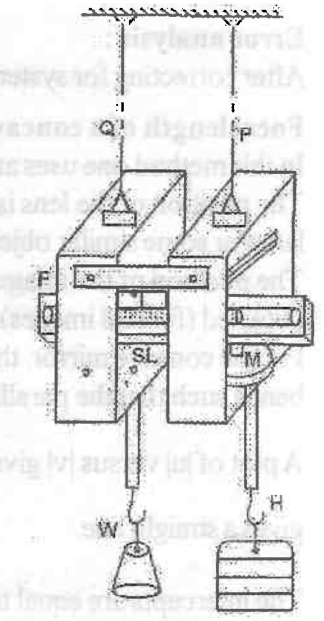
(a) **Systematic :** Error due to finite amplitude of the pendulum (as the motion is not exactly SHM). This may be corrected for by using the correct numerical estimate for the time period. However the practice is to ensure that the amplitude is small.

(b) **Statistical :** Errors arising from measurement of length and time.

$$\frac{\delta g}{g} = \frac{\delta L}{L} + 2\left(\frac{\delta T}{T}\right)$$

The contributions to δL, δT are both statistical and systematic. These are reduced by the process of averaging. The systematic error in L can be reduced by plotting several values of L vs T^2 and fitting to a straight line. The slope of this fit gives the correct value of L/T^2

(iii) Determination of Young's Modulus by Searle's Method

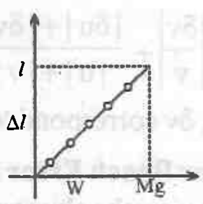


The experimental set up consists of two identical wires P and Q of uniform cross section suspended from a fixed rigid support. The free ends of these parallel wires are connected to a frame F as shown in the figure. The length of the wire Q remains fixed while the load L attached to the wire P through the frame F is varied in equal steps so as to produce extension along .the length. The extension thus produced is measured with the help of spirit level SL and micrometer screw M attached to the F frame on the side of the experimental wire. On placing the slotted weights on the hanger H upto a permissible value (half of the breaking force) the wire gets extended by small amount and the spirit level gets disturbed from horizontal setting. This increase in length is measured by turning the micrometer screw M upwards so as to restore the balance of the spirit level. If n be the number of turns of the micrometer screw and f be the difference in the cap reading, the increase in length Δl is obtained by

$$\Delta l = n \times \text{pitch} + f \times \text{least count}$$

The load on the hanger is reduced in the same steps and spirit level is restored to horizontal position. The mean of these two observations gives the true increase in length of the wire corresponding to the given value of load. From the data obtained, a graph showing extension (Δl) against the load (W) is plotted which is obtained as a straight line passing through the origin. The slope of the line gives

$$\tan\theta = \frac{l}{W} = \frac{l}{Mg}$$



Now, stress $= \dfrac{Mg}{\pi r^2}$ and strain $= \dfrac{l}{L}$

$$Y = \text{Stress/ strain} = \frac{MgL}{\pi r^2 l} = \frac{L}{\pi r^2 \tan\theta}$$

With known values of initial length L, radius r of the experimental wire and tanθ, Young's modulus Y can be calculated.

(iv) Specific Heat of a liquid using a calorimeter:

The principle is to take a known quantity of liquid in an insulated calorimeter and heat it by passing a known current (i) through a heating coil immersed within the liquid for a known length of time (t). The mass of the calorimeter (m_1) and, the combined mass of the calorimeter and the liquid (m_2) are measured. The potential drop across the heating coil is V and the maximum temperature of the liquid is measured to θ_2.

The specific heat of the liquid (S_l) is found by using the relation

$$(m_2 - m_1)S_l(\theta_2 - \theta_0) + m_1 S_c(\theta_2 - \theta_0) = i.\ V.\ t$$

or, $$(m_2 - m_1)S_l + m_1 S_c = i.\ V.\ t/(\theta_2 - \theta_0) \quad \ldots\ldots (1)$$

Here, θ_0 is the room temperature, while S_c is the specific heat of the material of the calorimeter and the stirrer. If S_c is known, then S_l can be determined.

On the other hand, if S_c is unknown: one can either repeat the experiment with water or a different mass of the liquid and use the two equations to eliminate $m_1 S_c$.

The sources of error in this experiment are errors due to improper connection of the heating coil, radiation, apart from statistical errors in measurement.

The direction of the current is reversed midway during the experiment to remove the effect of any differential contacts, radiation correction is introduced to take care of the second major source of systematic error.

Radiation correction: The temperature of the system is recorded for half the length of time t, i.e. t/2, where t is the time during which the current was switched on} after the current is switched off. The fall in temperature δ, during this interval is now added to the final temperature θ_2 to give the corrected final temperature:

$\theta'_2 = \theta_2 + \delta$

This temperature is used in the calculation of the specific heat, S_l.

Error analysis :

After correcting for systematic errors, equation (i) is used to estimate the remaining errors.

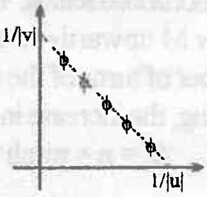
(v) **Focal length of a concave mirror and a convex lens using the u-v method.**

In this method one uses an optical bench and the convex lens (or the concave mirror) is placed on the holder. The position of the lens is noted by reading the scale at the bottom of the holder. A bright object (a filament lamp or some similar object) is placed at a fixed distance (u) in front of the lens (mirror).

The position of the image (v) is determined by moving a white screen behind the lens until a sharp image is obtained (for real images).

For the concave mirror, the position of the image is determined by placing a sharp object (a pin) on the optical bench such that the parallax between the object pin and the image is nil.

A plot of |u| versus |v| gives a rectangular hyperbola. A plot of $\frac{1}{|v|}$ vs $\frac{1}{|u|}$ gives a straight line.



The intercepts are equal to $\frac{1}{|f|}$, where f is the focal length.

Error : The systematic error in this experiment is mostly due to improper position of the object on the holder. This error maybe eliminated by reversing the holder (rotating the holder by 180° about the vertical) and then taking the readings again. Averages are then taken.

The equation for errors gives:

$$\left|\frac{\delta f}{f}\right| = \left|\frac{\delta u}{u}\right| + \left|\frac{\delta v}{v}\right| + \frac{|\delta u| + |\delta v|}{|u| + |v|}$$

The errors δu, δv correspond to the error in the measurement of u and v.

Index Error or Bench Error and its correction: In an experiment using an optical bench we are required to measure the object and image distances from the pole or vertex on the mirror. The distance between the tip of the needles and the pole of the mirror is the actual distance. But we practically measure distances between the indices with the help of the scale engraved on the bench. These distances are called the observed distances. The actual distances may not be equal to the observed distances and due to this reason an error creeps in the measurement of the distances. This error is called the index or the bench error.

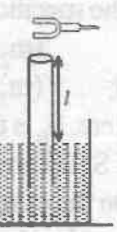
Index Error = Observed distance – actual distance and

Index Correction = Actual – observed distance

Note: Index correction whether positive or negative, is always added algebraically to the observed distance to get the corrected distance.

(vi) **Speed of sound using resonance column**

A tuning fork of known frequency (f) is held at the mouth of a long tube, which is dipped into water as shown in the figure. The length (l_1) of the air column in the tube is adjusted until it resonates with the tuning fork. The air temperature and humidity are noted. The length of the tube is adjusted again until a second resonance length (l_2) is found (provided the tube is long)



Then, $l_2 - l_1 - \lambda/2$, provided l_1, l_2 are resonance lengths for adjacent resonances.

∴ $\lambda = 2(l_2 - l_1)$, is the wavelength of sound.

Since the frequency f, is known; the velocity of sound in air at the temperature (θ) and humidity (h) is given by

$C = f\lambda = 2(l_2 - l_1)f$

It is also possible to use a single measurement of the resonant length directly, but, then it has to be corrected *for* the "end effect":

$\lambda(\text{fundamental}) = 4(l_1 + 0.3d)$, where d = diameter

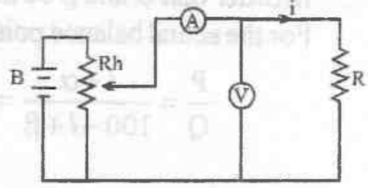
Errors : The major systematic errors introduced are due to end effects in (end correction) and also due to excessive humidity.

Random errors are given by

$$\frac{\delta C}{C} = \frac{\delta(l_2 - l_1)}{l_2 - l_1} = \frac{\delta l_2 + \delta l_1}{l_2 - l_1}$$

(vii) Verification of Ohm's law using voltmeter and ammeter

A voltmeter (V) and an ammeter (A) are connected in a circuit along with a resistance R as shown in the figure, along with a battery B and a rheostat, Rh Simultaneous readings of the current i and the potential drop V are taken by changing the resistance in the rheostat (Rh). A graph of V vs i is plotted and it is found to be linear (within errors).



The magnitude of R is determined by either

(a) taking the ratio $\frac{V}{i}$ and then

(b) fitting to a straight line: V = iR, and determining the slope R.

Errors :

Systematic errors in this experiment arise from the current flowing through V (finite resistance of the voltmeter), the Joule heating effect in the circuit and the resistance of the connecting wires/ connections of the resistance. The effect of Joule heating may be minimsed by switching on the circuit for a short while only, while the effect of finite resistance of the voltmeter can be overcome by using a high resistance instrument or a potentiometer. The lengths of connecting wires should be minimised as much as possible.

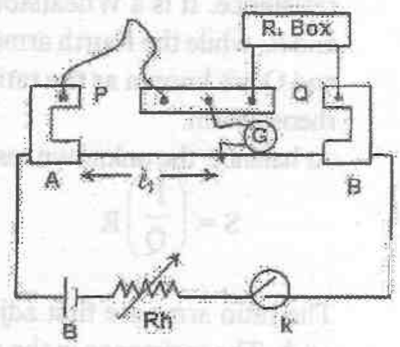
Error analysis :

The error in computing the ratio $R = \frac{V}{i}$ is given by $\left|\frac{\delta R}{R}\right| = \left|\frac{\delta V}{V}\right| + \left|\frac{\delta i}{i}\right|$

where δV and δi are of the order of the least counts of the instruments used.

(viii) Specific resistance of the material of a wire using a meter bridge :

A known length (l) of a wire is connected in one of the gaps (P) of a metre bridge, while a Resistance Box is inserted into the other gap (Q). The circuit is completed by using a battery (B), a Rheostat (Rh), a Key (K) and a galvanometer (G). The balance length (l) is found by closing key k and momentarily connecting the galvanometer until it gives zero deflection (null point). Then,



$$\frac{P}{Q} = \frac{l}{100 - l} \qquad ....(1)$$

using the expression for the meter bridge at balance. Here, represents the resistance of the wire while Q represents the resistance in the resistance box. The key K is open when the circuit is not in use.

The resistance of the wire, $P = \rho\frac{L}{\pi r^2} \Rightarrow \rho = \frac{\pi r^2}{L}P$ ....(2)

where r is the radius of wire and L is the length of the wire, r is measured using a screw gauge while L is measured with a scale.

Errors : The major systematic errors in this experiment are due to the heating effect, end corrections introduced due to shift of the zero of the scale at A and B, and stray resistances in P and Q, and errors due to non-uniformity of the meter bridge wire.

Error analysis : End corrections can be estimated by including known resistances P_1 and Q_1 in the two ends and finding the null point:

$$\frac{P_1}{Q_1} = \frac{l_1 + \alpha}{100 - l_1 + \beta}$$ ..... (2), where α and β are the end corrections.

When the resistance Q_1 is placed in the left gap and P_1 in the right gap,

$$\frac{Q_1}{P_1} = \frac{l_2 + \alpha}{100 - l_2 + \beta} \quad \text{..... (3)}$$

which give two linear equation for finding α and β.

In order that α and β be measured accurately, P_1 and Q_1 should be as different from each other as possible. For the actual balance point,

$$\frac{P}{Q} = \frac{l + \alpha}{100 - l + \beta} = \frac{l_1'}{l_2'},$$

Errors due to non-uniformity of the meter bridge wire can be minimised by interchanging the resistances in the gaps P and Q.

$$\therefore \quad \frac{\delta P}{P} = \left|\frac{\delta l_1'}{l_1'}\right| + \left|\frac{\delta l_2'}{l_2'}\right|$$

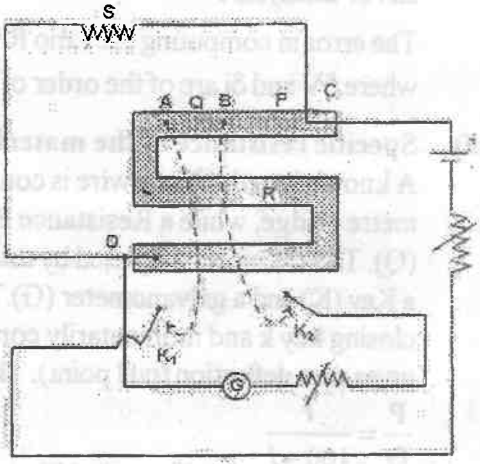
where, $\delta l'_1$ and $\delta l'_2$ are of the order of the least count of the scale.

The error is, therefore, minimum if $l'_1 = l'_2$ i.e. when the balance point is in the middle of the bridge. The error in ρ is

$$\frac{\delta P}{P} = \frac{2\delta r}{r} + \frac{\delta L}{L} + \frac{\delta P}{P}$$

(ix) Measurement of unknown resistance using a P.O. Box

A P.O. Box can also be used to measure an unknown resistance. It is a Wheatstone Bridge with three arms P, Q and R; while the fourth arm(s) is the unknown resistance. P and Q are known as the ratio arms while R is known at the rheostat arm.



At balance, the unknown resistance

$$S = \left(\frac{P}{Q}\right) R \quad \text{.....(1)}$$

The ratio arms are first adjusted so that they carry 100 Ω each. The resistance in the rheostat arm is now adjusted so that the galvanometer deflection is in one direction, if $R = R_0$ (Ohm) and in the opposite direction when $R = R_0 + 1$ (ohm).

This implies that the unknown resistance, S lies between R_0 and $R_0 + 1$ (ohm). Now, the resistance in P and Q are made 100 Ω and 1000 Ω respectively, and the process is repeated.

Equation (1) is used to compute S.

The ratio P/Q is progressively made 1 : 10, and then 1 : 100. The resistance S can be accurately measured.

Errors : The major sources of error are the connecting wires, unclear resistance plugs, change in resistance due to Joule heating, and the insensitivity of the Wheatstone bridge.

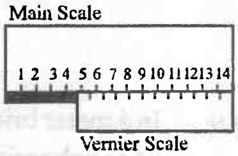
These may be removed by using thick connecting wires, clean plugs, keeping the circuit on for very brief periods (to avoid Joule heating) and calculating the sensitivity.

In order that the sensitivity is maximum, the resistance in the arm P is close to the value of the resistance S.

EXERCISE

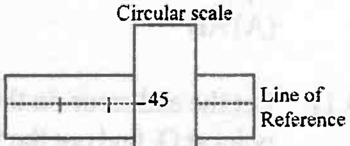
Q.1 In a Vernier Calipers (VC), N divisions of the main scale coincide with N + m divisions of the vernier scale. What is the value of m for which the instrument has minimum least count?
(A) 1 (B) N (C) Infinity (D) N/2

Q.2 Consider the vernier calipers as shown, the instrument has no zero error. What is the length of the rod shown, if 1 msd = 1mm? Use 7 msd = 8 vsd.
(A) 4.6 mm (B) 4.5 mm (C) 4.3 mm (D) none



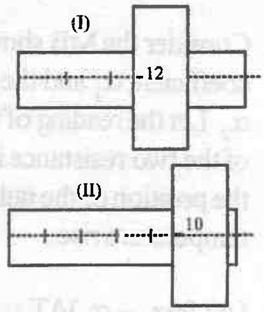
Q.3 In a vernier calipers the main scale and the vernier scale are made up different materials. When the room temperature increases by $\Delta T°C$, it is found the reading of the instrument remains the same. Earlier it was observed that the front edge of the wooden rod placed for measurement crossed the Nth main scale division and N + 2 msd coincided with the 2nd vsd. Initially, 10 vsd coincided with 9 msd. If coefficient of linear expansion of the main scale is α_1 and that of the vernier scale is α_2 then what is the value of α_1/α_2? (Ignore the expansion of the rod on heating)
(A) 1.8 / (N) (B) 1.8 /(N+2) (C) 1.8 / (N–2) (D) None

Q.4 Consider a screw gauge without any zero error. What will be the final reading corresponding to the final state as shown? It is given that the circular head translates P msd in N rotations. One msd is equal to 1mm.
(A) (P/N) (2 + 45/100) mm (B) (N/P) (2+45/N)mm
(C) P (2/N + 45/100)mm (D) $\left(2+\frac{45}{100}\times\frac{P}{N}\right)$ mm

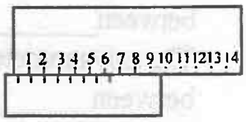


The circular scale has 100 divisions

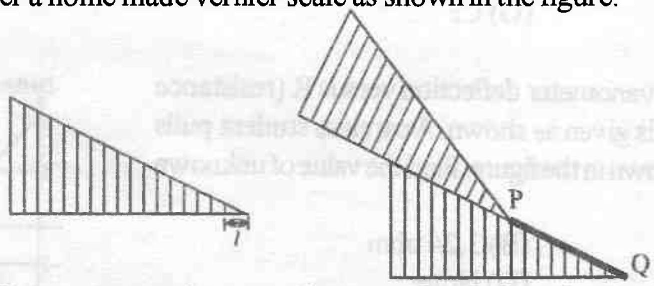
Q.5 A screw gauge has some zero error but its value is unknown. We have two identical rods. When the first rod is inserted in the screw, the state of the instrument is shown by diagram (I). When both the rods are inserted together in series then the state is shown by the diagram (II). What is the zero error of the instrument?
1 msd = 100 csd = 1mm
(A) –0.16 mm (B) +0.16 mm
(C) +0.14 mm (D) –0.14 mm



Q.6 The VC shown in the diagram has zero error in it (as you can see). It is given that 9 msd = 10 vsd.
(i) What is the magnitude of the zero error?
(ii) The observed reading of the length of a rod measured by this VC comes out to be 5.4 mm. If the vernier had been error free then ___ msd would have coincided with ___ vsd.



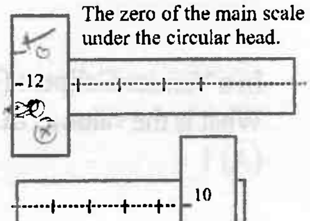
Q.7 Consider a home made vernier scale as shown in the figure.



In this diagram, we are interested in measuring the length of the line PQ. If the angle of both the inclines is equal to θ then what is the least count of the instrument.

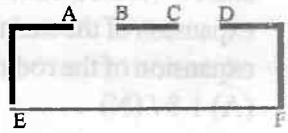
Q.8 The diagram shows the initial and the final state of SG, which has zero error in it. What can be the length of the object? 1 msd = 100 csd

The zero of the main scale lies under the circular head.



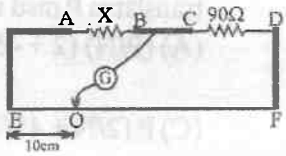
Q.9 In a meter bridge set up, which of the following should be the properties of the one meter long wire?
(A) High resistivity and low temperature coefficient
(B) Low resistivity and low temperature coefficient
(C) Low resistivity and high temperature coefficient
(D) High resistivity and high temperature coefficient

Q.10 Make the appropriate connections in the meter bridge set up shown. Resistance box is connected between _____. Unknown resistance is connected between______. Battery is connected between.



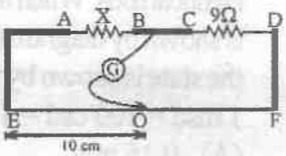
Options:
(A) AB (B) CD (C) EF (D) None

Q.11 Let the end error on the LHS and RHS be equal to one cm. For the balance point at O, find out the % tage error in the value of X? (If the end error is 1 cm from both sides then it means the corrected reading will become 10cm + 1cm from LHS and 90cm + 1cm from the RHS)



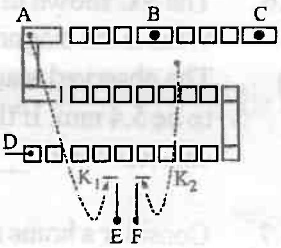
(A) 4.2% (B) 8.1% (C) 9.2% (D) None

Q.12 Consider the MB shown in the diagram, let the resistance X have temperature coefficient α_1 and the resistance from the RB have the temperature coefficient α_2. Let the reading of the meter scale be 10cm from the LHS. If the temperature of the two resistance increase by small temperature ΔT then what is the shift in the position of the null point? Neglect all the other changes in the bridge due to temperature rise.



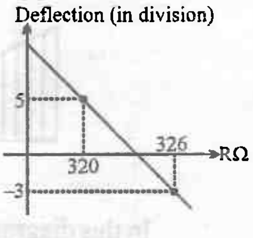
(A) $9(\alpha_1 - \alpha_2)\Delta T$ (B) $9(\alpha_1 + \alpha_2)\Delta T$ (C) $\frac{1}{9}(\alpha_1 + \alpha_2)\Delta T$ (D) $\frac{1}{9}(\alpha_1 - \alpha_2)\Delta T$

Q.13 The diagram shows an incomplete sketch of a PO box. Battery is connected between________. The unknown resistance is connected between
The galvanometer is connected between________. The key K_2 is connected between __________.



Options:
(A) CD (B) DA (C) CE (D) DF
(E) DE (F) BF (G) CF

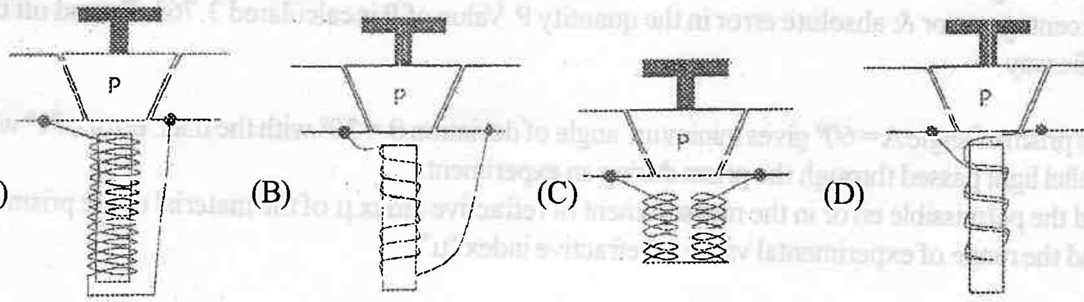
Q.14 For a post office Box, the graph of galvanometer deflection versus R (resistance pulled out of RB) for the ratio 100 : 1 is given as shown. A careless student pulls out two non consecutive values R as shown in the figure. Find the value of unknown resistance.



(A) 3.2 ohm (B) 3.24 ohm
(C) 3.206 ohm (D) None

Q.15 When we operate a wheat stone bridge then in starting the key of the battery is closed first and the key of the G is closed later. When the circuit is to be closed then switches are released in the opposite order. Why?
(A) Look at the diagram of the PO box, the switch is battery is always on the right hand hence it is easier to press it first.
(B) This is done to avoid the damage of the galvanometer due to induced emf.
(C) If the G switch is pressed before the battery switch then large sparking takes place at the battery switch.
(D) While disconnecting if we open the battery switch before the G switch then we can observe induced current in the circuit till the G switch is not opened.

Q.16 Identify which of the following diagrams represent the internal construction of the coils wound in a resistance box or PQ box?



Q.17 Which of the following reading is most accurate
(A) 4.00 cm (B) 0.004 mm (C) 40.00 cm (D) 4.00 m

Q.18 The least count of a stop watch is 1/5 sec. The time of 20 oscillations of a pendulum is measured to be 25 sec. The minimum percentage error in the measurement of time will be
(A) 0.1% (B) 0.8% (C) 1.8% (D) 8%

Q.19 A vernier callipers having 1 main scale division = 0.1 cm is designed to have a least count of 0.02 cm. If n be the number of divisions on vernier scale and m be the length of vernier scale, then
(A) n=10, m=0.5 cm (B) n=9, m=0.4 cm (C) n=10, m=0.8 cm (D) n=10 , m=0.2 cm

Q.20 Solve with due regard to significant digits
(i) $\sqrt{6.5-6.32}$ (ii) $\frac{2.91 \times 0.3842}{0.080}$

Q.21 A body travels uniformly a distance of (13.8 ± 0.2)m in time (4.0 ± 0.3) sec. Calculate its velocity.

Q.22 The main scale of a vernier calipers reads in millimeter and its vernier is divided into 10 divisions which coincide with 9 divisions of the main scale. When the two jaws of the instrument touch each other the seventh division of the vernier scale coincide with a scale division and the zero of the vernier lies to the right of the zero of main scale. Furthermore, when a cylinder is tightly placed along its length between the two jaws, the zero of the vernier scale lies slightly to the left of 3.2 cm and the fourth vernier division coincides with a scale division. Calculate the measured length of the cylinder.

Q.23 A short circuit occurs in a telephone cable having a resistance of 0.45 Ωm^{-1}. The circuit is tested with a Wheatstone bridge. The two resistors in the ratio arms of the Wheatstone bridge network have values of 100Ω and 1110Ω respectively. A balance condition is found when the variable resistor has a value of 400Ω. Calculate the distance down the cable, where the short has occurred.

Q.24 5.74 gm of a substance occupies a volume of 1.2 cm^3. Calculate its density with due regard for significant figures.

Q.25 The time period of oscillation of a simple pendulum is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The length of the pendulum is measured as $l = 10 \pm 0.1$cm and the time period as $T = 0.5 \pm 0.02$ s. Determine percentage error in the value of g.

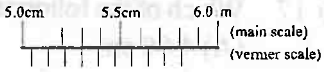
Q.26 A physical quantity P is related to four observables A, B, C and D as follows.

$$P = 4\pi^2 \frac{A^3 B^2}{\sqrt{C}\ D}$$

The percentage error of the measurement in A, B, C and D are 1%, 3% and 2%, 4% respectively. Determine the percentage error & absolute error in the quantity P. Value of P is calculated 3.763. Round off the result in scientific way.

Q.27 A glass prism of angle $A = 60^0$ gives minimum angle of deviation $\theta = 30^0$ with the max. error of 1^0 when a beam of parallel light passed through the prism during an experiment.
(i) Find the permissible error in the measurement of refractive index μ of the material of the prism.
(ii) Find the range of experimental value of refractive index 'μ'.

Q.28 In the given vernier calliper scale, the length of 1 main scale division is 1mm whereas the length of the vernier scale is 7.65 mm. Find the reading on the scale correct to significant digits as shown in the diagram.



ANSWER

Q.1	A	Q.2	B	Q.3	B	Q.4	D	Q.5	D	Q.6	(i) x = 0.6 msd, (ii) 6, 1st

Q.7 L.C $= l\left[\dfrac{1-\cos\theta}{\cos\theta}\right]$

Q.8 4 msd + 0.1 msd + 0.12 msd = 4.22 msd ; 4 msd + 0.1 msd + 1.12 msd = 5.22 msd & so on

Q.9 A Q.10 CD, AB, C Q.11 B Q.12 A Q.13 CE, CD, DF, BF

Q.14 B Q.15 B,C,D Q.16 D Q.17 C Q.18 B

Q.19 C Q.20 (i) 0.4 ; (ii) 14 Q.21 $v = (3.5 \pm 0.31)$ m/s

Q.22 3.07 cm Q.23 40 m Q.24 4.8 g/cm^3 Q.25 5%

Q.26 14%, 0.53, 3.76 Q.27 $5\pi/18\%$, $\sqrt{2}\left[1+\dfrac{\pi}{360}\right] > \mu > \sqrt{2}\left[1-\dfrac{\pi}{360}\right]$

Q.28 5.045 cm

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (PQRS & J)

FLUID MECHANICS

CONTENTS

KEY CONCEPTS

PART (A) - HYDROSTATICS

1. DENSITY AND RELATIVE DENSITY :

Density is mass per unit volume. Densities of solids and liquids are frequently compared with density of water and the relative density of a substance is defined as follows :

RELATIVE DENSITY with respect to water $= \dfrac{\text{density of the substance}}{\text{density of water}}$

$= \dfrac{\text{mass of any volume of substance}}{\text{mass of an equal volume of water}}$

(Also known as specific gravity of the substance).

Note that relative density being a ratio of same type of physical quantities, it is a number only, without any physical dimension .

2. PRINCIPLE OF ARCHIMEDES :

The principle of Archimedes states that any body, totally or partially immersed in a fluid, experiences an upward force or thrust which is equal to the weight of fluid it displaces and acts vertically up through the C. G. of the displaced fluid . The term fluid covers liquids and gases .

3. LAW OF FLOTATION :

If a body floats in equilibrium in a fluid, its entire weight is supported by the upward thrust of the fluid . Hence, the weight of a floating body is equal to the weight of the fluid displaced by the body at the equilibrium state .

4. FLUID PRESSURE :

Pressure at any point in a fluid is defined as the normal force (or thrust) exerted by the liquid on the surface per unit area .

Pressure is measured in dyne cm^{-2} in C G S units and in N m^{-2} in SI units, (also known as pascal).

[Note that pressure is a scalar quantity] .

When a plane surface is placed inside a liquid, the liquid exerts hydrostatic pressure on the surface, because of the weight of the liquid column above the surface . The total force exerted normally on the plane surface is called the thrust. The thrust over the surface is the vector sum of the thrusts over small area of the surface, over which the pressure can be considered to be uniform. Then :

(i) If the plane surface is horizontal, the pressure over the surface is uniform and the thrust = (area) × (the uniform pressure)

(ii) If the plane surface is rectangular with its plane vertical and a pair of sides horizontal, the thrust = (area) × (pressure at the centre of the area).

5. PRESSURE IN LIQUIDS :

The hydrostatics pressure 'p' at any point in a liquid varies directly.

(i) As the vertical height (h) of the point below the surface &

(ii) As the density (d) of the liquid.

It can be shown that $p = hdg$.

When a liquid is at rest, the pressure is same at all points at the same horizontal level . The pressure at a point in a liquid does not depend on either the shape of the vessel or the area of cross - section of the vessel.

6. PASCAL'S LAW :

Pressure applied to a liquid (at rest) at one point is transmitted equally in all directions throughout the liquid. This is known as Pascal's Law.

The compressibility of all liquids is exceedingly small & for all practical purposes, liquids may be considered incompressible. Hence, the density is constant throughout the liquid.

Pressure at a point in a liquid is the same in all directions and is perpendicular to the surface upon which its acts.

7. GUAGE PRESSURE AND TOTAL PRESSURE (ABSOLUTE PRESSURE):

The total pressure at any point in a liquid is the addition of :

(i) The pressure due to the liquid above the point. It is called guage pressure &

(ii) The atmospheric pressure acting on the surface of the liquid.

Thus total pressure = pressure due to liquid + atmospheric pressure

The total pressure is called absolute pressure.

8. THRUST DUE TO PRESSURE :

Total thrust on a horizontal surface immersed in a liquid = **(PRESSURE ON SURFACE)** × **(AREA OF SURFACE)**

Total thrust on a vertical surface immersed in a liquid =**(PRESSURE AT C.G. OF AREA)** × **(AREA OF SURFACE)**

PART (B) - HYDRODYNAMICS

1. The study of fluids in flow is called HYDRODYNAMICS.

2. VELOCITY - FIELD :

It is that space, where at every point in that space, there is a definite velocity. Then the space, where a fluid is in flow is a VELOCITY - FIELD.

3. FLOW - LINE :

In a velocity field is an imaginary line in that space, where the tangent to the line at any point on the line gives the direction of the velocity at that point. A flow line is also called a VELOCITY - LINE or a STREAM - LINE.

4. TYPES OF FLOW OF A FLUID :

Then the flow of a fluid can be classified as :

(i) A STREAM-LINE FLOW, the stream lines in the flow space remains steady as time progresses.

(ii) A TRUBULENT-FLOW, the stream lines in the flow space shift their positions as time progresses. In a STREAM-LINE FLOW, a group of stream lines form a tubular volume of the flow space, the surface of which is tangential to the stream lines, forming the lateral boundary of that tubular volume. Such a tubular volume in the flow space is a TUBE OF FLOW.

(iii) A steady state flow is the flow in which the fluid properties at any point in the velocity field do not change with time.

5. EQUATION OF CONTINUITY :

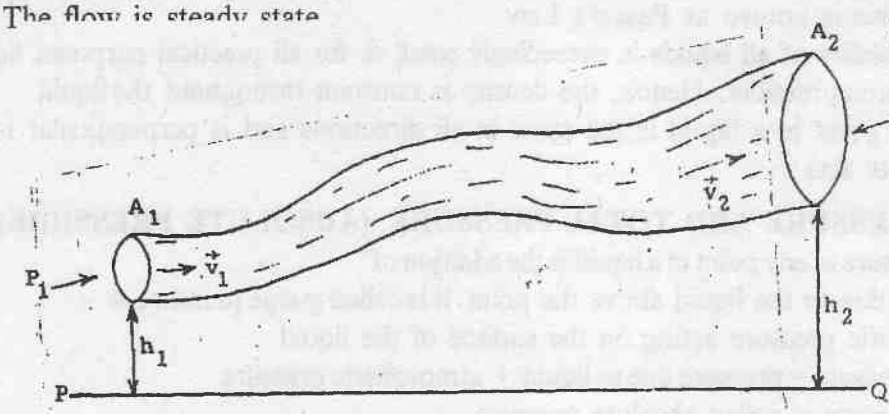
Equation of continuity states that for a steady state flow of a fluid in a pipe, the rate of mass flow across any cross section is constant.

$$\frac{dM}{dt} = \rho AV = \text{constant} .$$

If the fluid is incompressible density is constant at all points, hence, equation of continuity is AV = constant.

6. BERNOULLI'S EQUATION :

Consider a tube of flow in the space of the stream line flow of a fluid, in a uniform gravitational field. The flow is steady state.



Then :

$$\frac{P_1}{\rho}+\frac{V_1^2}{2}+gz_1=\frac{P_2}{\rho}+\frac{V_2^2}{2}+gz_2$$

Generalising and removing suffixes $\frac{P}{\rho}+\frac{V^2}{2}+gz$ = constant

This equation is called **BERNOULLI'S EQUATION** for steady, non-viscous and incompressible fluid flow.

SURFACE TENSION

1. **Surface Tension :** Surface tension of a liquid is the normal force acting per unit length on either side of an imaginary line drawn the free surface of a liquid. The direction of this force is perpendicular to the line and tangential to the free surface of liquid.

$$T=\frac{F}{L}$$

Note: The surface tension of a liquid varies with temperature as well as dissolved impurities, etc. When soap mixed with water, the surface tension of water decrease.

2. **Surface Energy :** If the area of the liquid surface has to be increased work has to be done against the force of surface tension. The work done to form a film is stored as potential energy in the surface.

$$W = T\,\Delta A$$

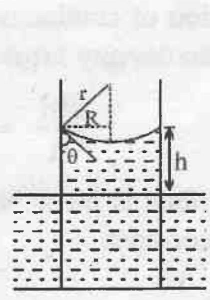
3. **Excess Pressure :** Excess pressure inside a liquid drop

$$\Delta p=\frac{2T}{r}$$

For a soap bubble in air, there are two surfaces, and so,

$$\Delta p = 2\times\frac{2T}{r}=\frac{4T}{r}$$

4. **Capillarity :** Water in the capillary rises to a height

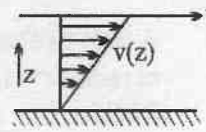


$$h=\frac{2T}{rg\rho}$$

where r is the radius of meniscus, and $r=\frac{R}{\cos\theta}$ where θ is the angle of contact and thus $h=\frac{2T\cos\theta}{R\rho g}$

VISCOSITY

If a glass plate in contact with a water column of height h is moved with constant velocity v. Forces of viscosity appear between the solid surface and the layer in contact.



$$F = -\eta A \frac{dv}{dz}$$

where h is a consant called coefficient of viscosity, its cgs unit is poise.
Dimension is ML^1T^{-1}. The SI units of viscosity equal to 10 poise.

Stoke's Law and Terminal Velocity

When a sphere of radius r moves with a velocity v through a fluid of viscosity h, the viscous force opposing the motion of the sphere is

$$F = 6\pi\eta r v$$

If for a sphere viscous force become equal to the net weight acing downward, the velocity of the body become constant and is known as terminal velocity.

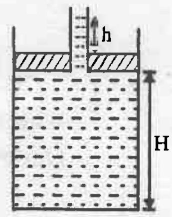
$$6\pi\eta r v_T = \frac{4}{3}\pi r^3(\rho - \sigma)g$$

$$\Rightarrow \quad v_T = \frac{2}{9} r^2 \left\{\frac{\rho - \sigma}{\eta}\right\} g$$

EXERCISE # I

Q.1 A spherical tank of 1.2 m radius is half filled with oil of relative density 0.8. If the tank is given a horizontal acceleration of 10 m/s^2. Calculate the inclination of the oil surface to horizontal and maximum pressure on the tank.

Q.2 A piston of mass M = 3kg and radius R = 4cm has a hole into which a thin pipe of radius r = 1cm is inserted. The piston can enter a cylinder tightly and without friction, and initially it is at the bottom of the cylinder. 750gm of water is now poured into the pipe so that the piston & pipe are lifted up as shown. Find the height H of water in the cylinder and height h of water in the pipe.



Q.3 A rectangular vessel is filled with water & oil in equal proportion (by volume), the oil being twice lighter than water. Show that the force on each wall of the vessel will be reduced by one fifth if the vessel is filled only with oil. (take into consideration the fact that the oil is found at the top of the vessel).

Q.4 A solid ball of density half that of water falls freely under gravity from a height of 19.6 m and then enter water. Upto what depth will the ball go? How much time will it take to come again to the water surface? Neglect air resistance & velocity effects in water.

Q.5 Place a glass beaker, partially filled with water, in a sink. The beaker has a mass 390 gm and an interior volume of 500cm^3. You now start to fill the sink with water and you find, by experiment, that if the beaker is less than half full, it will float; but if it is more than half full, it remains on the bottom of the sink as the water rises to its rim. What is the density of the material of which the beaker is made?

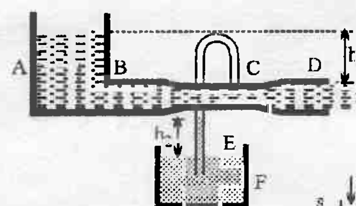
Q.6 Two spherical balls A and B made up of same material having masses 2m and m are released from rest. Ball B lies at a distance h below the water surface while A is at a height of 2h above water surface in the same vertical line, at the instant they are released.

(a) Obtain the position where they collide.

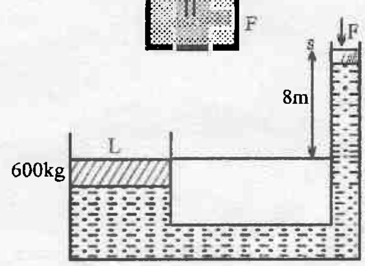
(b) If the bodies stick together due to collision, to what maximum height above water surface does the combined mass rise?

Specific gravity of the material of the balls is 2/3. Neglect viscosity and loss due to splash.

Q.7 Two very large open tanks A and F both contain the same liquid. A horizontal pipe BCD, having a constriction at C leads out of the bottom of tank A, and a vertical pipe E opens into the constriction at C and dips into the liquid in tank F. Assume streamline flow and no viscosity. If the cross section at C is one half that at D and if D is at a distance h_1 below the level of liquid in A, to what height h_2 (in terms of h_1) will liquid rise in pipe E ?



Q.8 For the system shown in the figure, the cylinder on the left at L has a mass of 600kg and a cross sectional area of 800 cm^2. The piston on the right, at S, has cross sectional area 25cm^2 and negligible weight. If the apparatus is filled with oil. (ρ = 0.75 gm/cm^3) Find the force F required to hold the system in equilibrium.

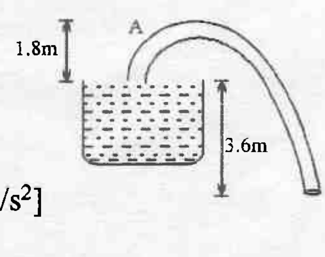


Q.9 A siphon has a uniform circular base of diameter $\frac{8}{\sqrt{\pi}}$ cm with its crest A 1.8 m above water level as in figure. Find

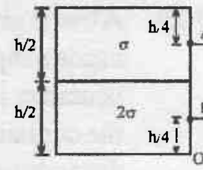
(a) velocity of flow

(b) discharge rate of the flow in m^3/sec.

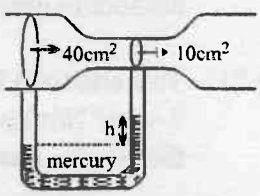
(c) absolute pressure at the crest level A. [Use P_0 = 10^5 N/m^2 & g = 10m/s^2]



Q.10 A large tank is filled with two liquids of specific gravities 2σ and σ. Two holes are made on the wall of the tank as shown. Find the ratio of the distances from O of the points on the ground where the jets from holes A & B strike.



Q.11 The horizontal pipe shown in the diagram has a cross sectional area of $40cm^2$ at the wider position and $10cm^2$ at the narrow poriton. A liquid of specific gravity 1.6 is flowing in the pipe with volume flow rate equal to 5×10^{-3} m^3/s. Find the difference in the heights h between the mercury column in the manometer tube. ($\rho_{mg} = 13.6 \times 10^3$ kg/m^3)

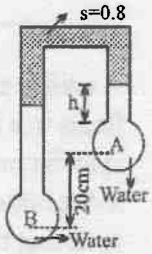


Q.12(a) A spherical tank of 1.2m radius is half filled with oil of relative density 0.8. If the tank is given a horizontal acceleration of $10 m/s^2$. Calculate the inclination of the oil surface to horizontal and maximum pressure on the tank.

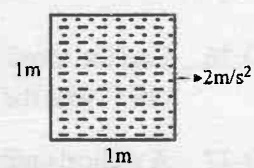
(b) The volume of an air bubble is doubled as it rises from the bottom of a lake to its surface. If the atmospheric pressure is H m of mercury & the density of mercury is n times that of lake water. Find the depth of the lake.

Q.13 A test tube of thin walls has some lead shots in it at its bottom and the system floats vertically in water, sinking by a length $l_o = 10$ cm. A liquid of density less than that of water, is poured into the tube till the levels inside and outside the tube are even. If the tube now sinks to a length $l_o = 40$ cm, the specific gravity of the liquid is ________.

Q.14 For the arrangement shown in the figure the value of h if the pressure difference between the vessel A and B is $3 kN/m^2$ is ______.



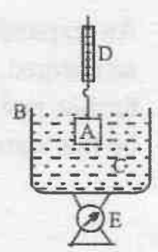
Q.15 An open cubical tank completely filled with water is kept on a horizontal surface. Its acceleration is then slowly increased to $2m/s^2$ as shown in the Fig. The side of the tank is 1m. Find the mass of water that would spill out of the tank.



Q.16 In air an object weighs 15N, when immersed completely in water the same object weighs 12N. When immersed in another liquid completely, it weighs 13N. Find
(a) the specific gravity of the object and
(b) the specific gravity of the other liquid.

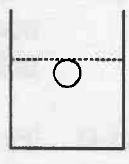
Q.17 Compute the work which must be performed to slowly pump the water out of a hemispherical reservoir of radius R – 0.6 m.

Q.18 Block A in figure hangs by a cord from spring balance D and is submerged in a liquid C contained in a beaker B. The mass of the beaker is 1kg & the mass of the liquid is 1.5 kg. The balance D reads 2.5 kg & balance E reads 7.5 kg.. The volume of block A is 0.003 m^3.
(i) What is the density of block & the liquid.
(ii) What will each balance read if block is pulled out of the liquid.



Q.19 A solid cube, with faces either vertical or horizontal, is floating in a liquid of density 6 g/cc. It has two third of its volume submerged. If enough water is added from the top so as to completely cover the cube, what fraction of its volume will remain immersed in the liquid?

Q.20 A ball is given velocity v_0 (greater than the terminal velocity v_T) in downward direction inside a highly viscous liquid placed inside a large container. The height of liquid in the container is H. The ball attains the terminal velocity just before striking at the bottom of the container. Draw graph between velocity of the ball and distance moved by the ball before getting terminal velocity.

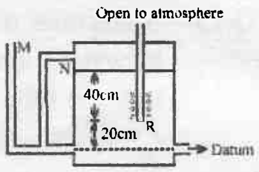


Q.21 Two arms of a U-tube have unequal diameters $d_1 = 1.0$ mm and $d_2 = 1.0$ cm. If water (surface tension 7×10^{-2} N/m) is poured into the tube held in the vertical position, find the difference of level of water in the U-tube. Assume the angle of contact to be zero.

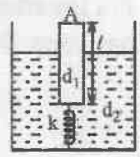
Q.22 A spherical ball of radius 1×10^{-4} m and density 10^4 kg/m^3 falls freely under gravity through a distance h before entering a tank of water. If after entering the water the velocity of the ball does not change, find h. The viscosity of water is 9.8×10^{-6} N-s/m^2.

Q.23 Calculate the rate of flow of glycerine of density 1.25×10^3 kg/m^3 through the conical section of a pipe if the radii of its ends are 0.1m & 0.04m and the pressure drop across its length is 10N/m^2.

Q.24 The tank in fig discharges water at constant rate for all water levels above the air inlet R. The height above datum to which water would rise in the manometer tubes M and N respectively are ________ & ________.



Q.25 A uniform cylindrical block of length l density d_1 and area of cross section A floats in a liquid of density d_2 contained in a vessel ($d_2 > d_1$). The bottom of the cylinder just rests on a spring of constant k. The other end of the spring is fixed to the bottom of the vessel. The weight that may be placed on top of the cylinder such that the cylinder is just submerged in the liquid is ____



Q.26 Find the speed of rotation of 1 m diameter tank, initially full of water such that water surface makes an angle of 45^0 with the horizontal at a radius of 30 cm. What is the slope of the surface at the wall of the tank.

Q.27 A vertical uniform U tube open at both ends contains mercury. Water is poured in one limb until the level of mercury is depressed 2cm in that limb. What is the length of water column when this happens.

Q.28 A piece of copper having an internal cavity weigh 264gm in air and 221gm in water. Find the volume of cavity. Density of copper is 8.8 gm/cc.

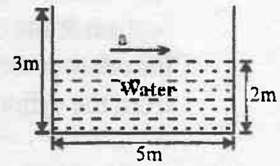
Q.29 A vessel contains oil density = 0.8gm/cm^3. A homogeneous sphere floats with half its volume immersed in mercury and the other half in oil. The density of the material of the sphere in gm/cm^3 is ________

Q.30 An expansible balloon filled with air floats on the surface of a lake with 2/3 of its volume submerged. How deep must it be sunk in the water so that it is just in equilibrium neither sinking further nor rising ? It is assumed that the temperature of the water is constant & that the height of the water barometer is 9 meters.

EXERCISE # II

Q.1 A solid block of volume $V=10^{-3}m^3$ and density $d=800kg/m^3$ is tied to one end of a string, the other end of which is tied to the bottom of the vessel. The vessel contains 2 immiscible liquids of densities $\rho_1=1000kg/m^3$ and $\rho_2=1500kg/m^3$. The solid block is immersed with 2/5th of its volume in the liquid of higher density & 3/5th in the liquid of lower density. The vessel is placed in an elevator which is moving up with an acceleration of $a=g/2$. Find the tension in the string. $[g=10m/s^2]$

Q.2 An open rectangular tank 5m × 4m × 3m high containing water upto a height of 2m is accelerated horizontally along the longer side.

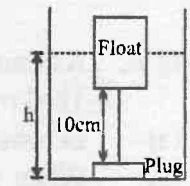


(a) Determine the maximum acceleration that can be given without spilling the water.

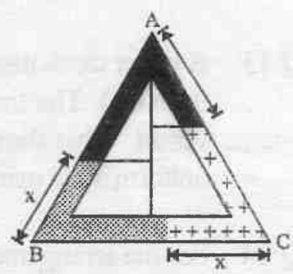
(b) Calculate the percentage of water split over, if this acceleration is increased by 20%.

(c) If initially, the tank is closed at the top and is accelerated horizontally by $9m/s^2$, find the gauge pressure at the bottom of the front and rear walls of the tank.

Q.3 A level controller is shown in the figure. It consists of a thin circular plug of diameter 10cm and a cylindrical float of diameter 20cm tied together with a light rigid rod of length 10cm. The plug fits in snugly in a drain hole at the bottom of the tank which opens into atmosphere. As water fills up and the level reaches height h, the plug opens. Find h. Determine the level of water in the tank when the plug closes again. The float has a mass 3kg and the plug may be assumed as massless.

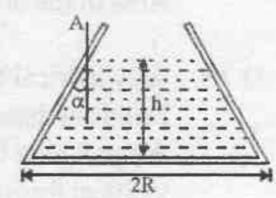


Q.4 A closed tube in the form of an equilateral triangle of side l contains equal volumes of three liquids which do not mix and is placed vertically with its lowest side horizontal. Find x in the figure if the densities of the liquids are in A.P.



Q.5 A ship sailing from sea into a river sinks X mm and on discharging the cargo rises Y mm. On proceeding again into sea the ship rises by Z mm. Assuming ship sides to be vertical at water line, find the specific gravity of sea water.

Q.6 A conical vessel without a bottom stands on a table. A liquid is poured with the vessel & as soon as the level reaches h, the pressure of the liquid raises the vessel. The radius of the base of the vessel is R and half angle of the cone is α and the weight of the vessel is W. What is the density of the liquid ?



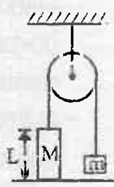
Q.7 As the arrangement shown in the fig is released the rod of mass M moves down into the water. Friction is negligible and the string is inextensible.

(a) Find the acceleration of the system w.r.t. the distance moved by each mass.

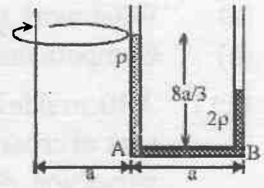
(b) Find the time required to completely immerse the rod into water

if $\frac{m}{M} = \frac{\rho - \rho_{water}}{\rho}$.

ρ = density of rod ; ρ_{water} = density of water

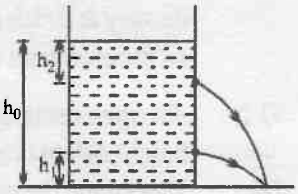


Q.8 The interface of two liquids of densities ρ and 2ρ respectively lies at the point A in a U tube at rest. The height of liquid column above A is 8a/3 where AB=a. The cross sectional area of the tube is S. With what angular velocity the tube must be whirled about a vertical axis at a distance 'a' such that the interface of the liquids shifts towards B by 2a/3.



Q.9 A closed cylindrical tank 2m high & 1 m in diameter contains 1.5 m of water. When the angular velocity is constant at 20.0 rad/s, how much of the bottom of the tank is uncovered? (The cylinder is rotated about vertical axis of symmetry passing through its length.)

Q.10 A cylinder of height H is filled with water to a height h_0 ($h_0 < H$), & is placed on a horizontal floor. Two small holes are punched at time t = 0 on the vertical line along the length of the cylinder, one at a height h_1 from the bottom & the other a depth h_2 below the level of water in the cylinder. Find the relation between h_1 & h_2 such that the instantaneous water jets emerging from the cylinder from the two holes will hit the ground at the same point.



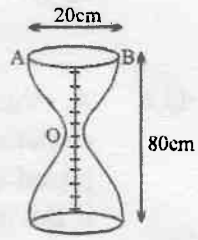
Q.11 A cylindrical tank with a height of h = 1m is filled with water up to its rim. What time is required to empty the tank through an orifice in its bottom? The cross sectional area of the orifice is (1/400)th of the tank. Find the time required for the same amount of water to flow out of the tank if the water level in the tank is maintained constant at a height of h = 1m from the orifice.

Q.12 A Conical funnel whose height H=20cm is filled with water. The radius of the upper opening R – 12 cm. The lower opening through which the water begins to flow out of the funnel has the radius r = 0.3 cm.

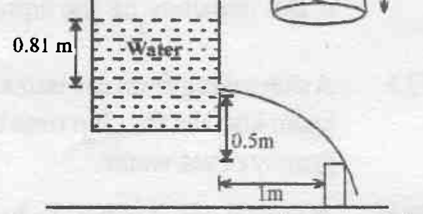
(a) In what time is the water level in the funnel lowered by 5 cm ?

(b) When will the funnel be emptied ?

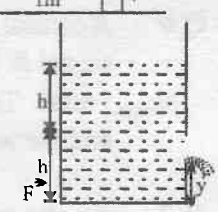
Q.13 A water clock used in ancient Greek is designed as a closed vessel with a small orifice O. The time is determined according to the level of the water in the vessel. What should be the shape of the vessel be for the time scale to be uniform. Find mathematical equation governing curve AOB.



Q.14 For the arrangement shown in the figure. Find the time interval after which the water jet ceases to cross the wall.
Area of the tank = 0.5 m^2.
Area of the orifice = 1 cm^2.



Q.15 A cylindrical tank having cross-sectional area A = 0.5 m^2 is filled with two liquids of density ρ_1 = 900 kgm^{-3}, to a height h = 60cm as shown in the figure. A small hole having area a = 5 cm^2 is made in right vertical wall at a height y=20cm from the bottom. Calculate



(i) velocity of efflux.

(ii) horizontal force F to keep the cylinder in static equilibrium, if it is placed on a smooth horizontal plane.

(iii) minimum and maximum value of F to keep the cylinder at rest. The coefficient of friction between cylinder and the plane is m = 0.01.

(iv) velocity of the top most layer of the liquid column and also the velocity of the boundary separating the two liquids.

Q.16 A cylindrical wooden float whose base area S = 4000 cm^2 & the altitude H = 50 cm drifts on the water surface. Specific weight of wood d = 0.8 gf/cm^3.

(a) What work must be performed to take the float out of the water ?

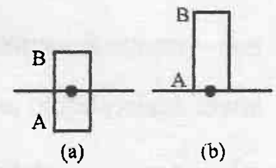
(b) Compute the work to be performed to submerge completely the float into the water.

Q.17 A 10cm side cube weighing 5N is immersed in a liquid of relative density 0.8 contained in a rectangular tank of cross sectional area 15cm x 15cm. If the tank contained liquid to a height of 8cm before the immersion, determine the levels of the bottom of the cube and the liquid surface.

Q.18 A jug contains 15 glasses of orange juice. When you open the tap at the bottom it takes 12 sec to fill a glass with juice. If you leave the tap open. how long will it take to fill the remaining 14 glasses and thus empty the jug?

Q.19 An interstellar explorer discovers a remarkable planet made entirely of a uniform incompressible fluid on density ρ. The radius of the planet is R and the acceleration of gravity at its surface is g. What is the pressure at the center of the planet.

Q.20 A cylindrical rod of length $l = 2$m & density $\frac{\rho}{2}$ floats vertically in a liquid of density ρ as shown in Fig (a).

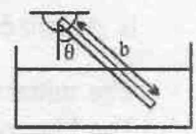


(a) Show that it performs SHM when pulled slightly up & released & find its time period. Neglect change in liquid level.

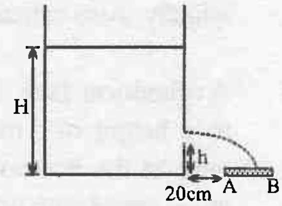
(b) Find the time taken by the rod to completely immerse when released from position shown in (b). Assume that it remains vertical throughout its motion. (take $g = \pi^2$ m/s^2)

Q.21 A uniform cylinder of a light material of length $l = 0.8$m and radius of cross section $r = 0.01$ m floats on a liquid of specific density $\rho = 0.9$ upto half its length. The container of the liquid is a long cylindrical beaker of radius $R = 0.04$m. Another perfectly immiscible liquid of specific density $\sigma = 0.6$ is now slowly poured all along the inner periphery of the beaker at a uniform rate of $v = 0.25 \times 10^{-4}$ m^3/s and it spreads itself uniformly over the first liquid. Find the velocity with which the cylinder will rise or sink in the liquid.

Q.22 A uniform rod of length b capable of tuning about its end which is out of water, rests inclined to the vertical. If its specific gravity is 5/9, find the length immersed in water.



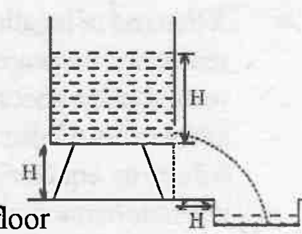
Q.23 An open cylindrical vessel of large cross-section A contains liquid upto a height H = 120cm. After an orifice of area A/1000 at a height of h = 20cm is opened.



(a) Calculate liquid heights above orifice for which it falls on both ends of horizontal plate.

(b) How long will the liquid be falling on the plate.
Given : plate AB is of length 60cm. (g = 10m/s^2)

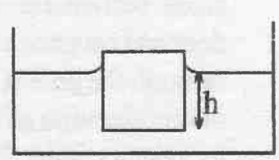
Q.24 A cylindrical vessel of height H = 4 m & area of cross section 1 m^2 filled with water rests on a stand of same height H. It has a small plugged hole near its bottom. When plug is removed the liquid starts to come out.



(a) Find the range of the liquid as a function of instantaneous height of the liquid in the upper vessel

(b) Find the volume of liquid collected in a large initially empty vessel lying on floor at a distance H from the stand.
Assume that water falling on to the floor does not flow into the vessel.

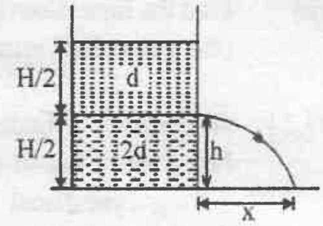
Q.25 A cube with a mass 'm' completely wettable by water floats on the surface of water. Each side of the cube is 'a'. What is the distance h between the lower face of cube and the surface of the water if surface tension is S. Take density of water as ρ_w. Take angle of contact m zero.



EXERCISE # III

Q.1 A horizontal pipe line carries water in a streamline flow. At a point along the pipe where the cross-sectional area is 10 cm², the water velocity is $1\ ms^{-1}$ & the pressure is 2000 Pa. The pressure of water at another point where the cross sectional area is 5 cm², is ________ pa.
[Density of water = 10^3 kg. m^{-3}] [JEE '94 , 2]

Q.2 A container of large uniform cross–sectional area A resting on a horizontal surface, holds two immiscible, non–viscous & incompressible liquids of densities d & 2d , each of height $\frac{H}{2}$ as shown in figure . The lower density liquid is open to the atmosphere having pressure P_0 .



(a) A homogeneous solid cylinder of length L $\left(L < \frac{H}{2}\right)$ cross–sectional area $\frac{A}{5}$ is immersed such that it floats with its axis vertical at the liquid–liquid interface with the length $\frac{L}{4}$ in the denser liquid. Determine :

(i) The density D of the solid &

(ii) The total pressure at the bottom of the container.

(b) The cylinder is removed and the original arrangement is restored . A tiny hole of area s (s << A) is punched on the vertical side of the container at a height h $\left(h < \frac{H}{2}\right)$. Determine :

(i) The initial speed of efflux of the liquid at the hole ;

(ii) The horizontal distance x travelled by the liquid initially &

(iii) The height h_m at which the hold should be punched so that the liquid travels the maximum distance x_m initially. Also calculate x_m . [Neglect the air resistance in these calculations]. [JEE '95 , 10]

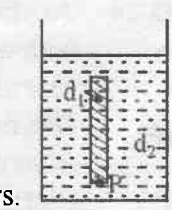
Q.3 A cylindrical tank 1 m in radius rests on a platform 5 m high . Initially the tank is filled with water to a height of 5 m . A plug whose area is 10^{-4} m² is removed from an orifice on the side of the tank at the bottom . Calculate the following :

(i) initial speed with which the water flows from the orifice ;

(ii) initial speed with which the water strikes the ground &

(iii) time taken to empty the tank to half its original value . [REE '95 , 5]

Q.4 A thin rod of length L & area of cross-section S is pivoted at its lowest point P inside a stationary, homogeneous & non-viscous liquid (Figure). The rod is free to rotate in a vertical plane about a horizontal axis passing through P. The density d_1 of the material of the rod is smaller than the entity d_2 of the liquid. The rod is displaced by a small angle θ from its equilibrium position and then released. Show that the motion of the rod is simple harmonic and determine its angular frequency in terms of the given parameters.



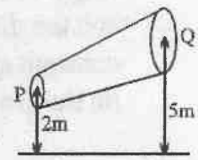
[JEE '96 , 5]

Q.5 A large open top container of negligible mass & uniform cross–sectional area A has a small hole of cross–sectional area A/100 in its side wall near the bottom . The container is kept on a smooth horizontal floor and contains a liquid of density ρ and mass m . Assuming that the liquid starts flowing out horizontally through the hole at t = 0, calculate

(i) the acceleration of the container and

(ii) its velocity when 75 % of the liquid has drained out . [JEE '97 , 5]

Q.6 A nonviscous liquid of constant density 1000 kg/m^3 flows in a streamline motion along a tube of variable cross section. The tube is kept inclined in the vertical plane as shown in the figure. The area of cross section of the tube at two points P and Q at heights of 2 meters and 5 meters are respectively 4×10^{-3}m^2 and 8×10^{-3} m^3. The velocity of the liquid at point P is 1 m/s. Find the work done per unit volume by the pressure and the gravity forces as the fluid flows from point P to Q. [JEE '97]



Q.7 Water from a tap emerges vertically downwards with an initial speed of 1.0 ms^{-1}. The cross–sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water, and that the flow is steady. The cross–sectional area of the stream 0.15 m below the tap is [JEE '98, 2]
(A) 5.0×10^{-4} m^2 (B) 1.0×10^{-5} m^2 (C) 5.0×10^{-5} m^2 (D) 2.0×10^{-5}m^2

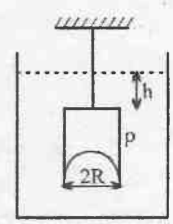
Q.8 A wooden stick of length l, and radius R and density ρ has a small metal piece of mass *m* (of negligible volume) attached to its one end. Find the minimum value for the mass *m* (in terms of given parameters) that would make the stick float vertically in equilibrium in a liquid of density σ (>ρ). [JEE '99, 10]

Q.9 A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth 4y from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both holes are the same. Then, R is equal to:

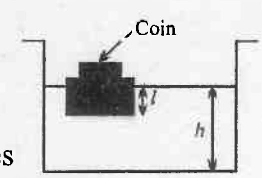
(A) $\frac{L}{\sqrt{2\pi}}$ (B) 2πL (C) L (D) $\frac{L}{2\pi}$

[JEE 2000 (Scr.)]

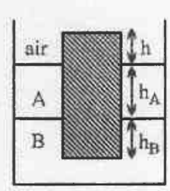
Q.10 A hemispherical portion of radius R is removed from the bottom of a cylinder of radius R. The volume of the remaining cylinder is V and its mass is M. It is suspended by a string in a liquid of density ρ where it stays vertical. The upper surface of the cylinder is at a depth h below the liquid surface. The force on the bottom of the cylinder by the liquid is [JEE 2001 (Scr.)]
(A) Mg (B) Mg – v ρ g
(C) Mg + π R^{2}h ρ g (D) ρg (V + πR^{2}h)



Q.11 A wooden block, with a coin placed on its top, floats in water as shown in figure. The distances *l* and *h* are shown there. After some time the coin falls into the water. Then [JEE 2002 (Scr.)]
(A) *l* decreases and *h* increases (B) *l* increases and *h* decreases
(C) both *l* and *h* increase (D) both *l* and *h* decrease

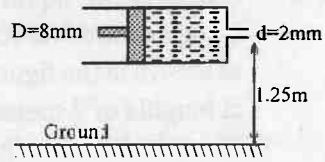


Q.12 A uniform solid cylinder of density 0.8 gm/cm^3 floats in equilibrium in a combination of two non mixing liquids A and b with its axis vertical. The densities of the liquids A and B are 0.7 gm/cm^3 and 1.2 g/cm^3, respectively. The height of liquid A is h_A = 1.2 cm. The length of the part of the cylinder immersed in liquid B is h_B = 0.8 cm.



(a) Find the toal force exerted by liquid A on the cylinder.
(b) Find h, the length of the part of the cylinder in air.
(c) The cylinder is depressed in such a way that its top surface is just below the upper surface of liquid A and is then released. Find the acceleration of the cylinder immediately after it is released. [JEE 2002]

Q.13 Consider a horizontally oriented syringe containing water located at a height of 1.25 m above the ground. The diameter of the plunger is 8 mm and the diameter of the nozzle is 2 mm. The plunger is pushed with a constant speed of 0.25 m/s. Find the horizontal range of water stream on the ground. Take g = 10 m/s2. [JEE 2004]



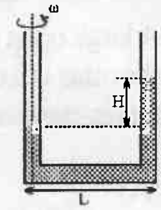
Q.14 A solid sphere of radius R is floating in a liquid of density ρ with half of its volume submerged. If the sphere is slightly pushed and released, it starts performing simple harmonic motion. Find the frequency of these oscillations. [JEE 2004]

Q.15 Water is filled in a container upto height 3m. A small hole of area 'a' is punched in the wall of the container at a height 52.5 cm from the bottom. The cross sectional area of the container is A. If $\frac{a}{A}$ =0.1 then v^2 is (where v is the velocity of water coming out of the hole)

(A) 48 (B) 51 (C) 50 (D) 51.5

[JEE' 2005 (Scr)]

Q.16 A U tube is rotated about one of it's limbs with an angular velocity ω. Find the difference in height H of the liquid (density ρ) level, where diameter of the tube d << L. [JEE 2005]



ANSWER KEY

EXERCISE # I

Q.1 $45^0, 9600\sqrt{2}$ (gauge)N/m^2

Q.2 $h = \frac{2m}{\pi}$, $H = \frac{11}{32\pi}$ m

Q.4 19.6 m, 4 sec

Q.5 2.79 gm/cc

Q.6 at the water surface, h/2

Q.7 $h_2 = 3\ h_1$

Q.8 37.5 N

Q.9 (a) $6\sqrt{2}$ m/s, (b) $9.6\sqrt{2} \times 10^{-3}$M^3/sec, (c) 4.6×10^4 N/m^2

Q.10 $\sqrt{3} : \sqrt{2}$

Q.11 $\frac{375}{24} = 15.6$ cm

Q.12 (a)$9600\sqrt{2}$, (b) nH

Q.13 0.75

Q.14 – 0.5 m,, 2.5 m

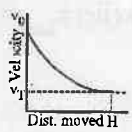
Q.15 100kg

Q.16 (a) 5, (b) 2/3

Q.17 101.8 Kgf–m

Q.18 (i) 2500 kg/m^3, $\frac{5000}{3}$ kg/m^3, (ii) $R_D = 7.5$ kg, $R_E = 2.5$ kg

Q.19 3/5

Q.20 

Q.21 2.5 cm

Q.22 20.4 m

Q.23 6.43×10^{-4} m^3/s

Q.24 20cm, 60cm

Q.25 $\ell(d_2 - d_1)\left(\frac{k}{d_2} + Ag\right)$

Q.26 $\omega = \frac{10}{\sqrt{3}}$ rad/s, $\tan\alpha = \frac{5}{3}$

Q.27 54.4 cm

Q.28 13cc

Q.29 7.2gm/cm^3

Q.30 4.5m

EXERCISE # II

Q.1 6N

Q.2 4m/s^2, 10%, 0, 45kPa

Q.3 $h_1 = \frac{2(3+\pi)}{15\pi} = 0.26$; $h_2 = \frac{3+\pi}{10\pi} = 0.195$

Q.4 x = 1/3

Q.5 $\frac{Y}{y-x+z}$

Q.6 $\rho = \frac{W}{\pi h^2 g \tan\alpha\left(R - \frac{1}{3}h\tan\alpha\right)}$

Q.7 (a) $\left(\frac{M-m}{M+m}\right)g - \frac{(M-m)gx}{(M+m)L}$ (b) $t = \frac{\pi}{2}\sqrt{\frac{L}{g}\left(\frac{M+m}{M-m}\right)}$

Q.8 $\sqrt{\frac{18g}{19a}}$

Q.9 $\frac{\pi}{80}$ m^2

Q.10 $h_1 = h_2$

Q.11 $80\sqrt{5}$ sec, $40\sqrt{5}$ sec

Q.12 (a) 33.2 s, (b) 64.6 s Q.13 $y = 4\times10^{-3} x^4$ Q.14 431 sec

Q.15 (i) 4m/s, (ii) F = 7.2N, (iii) $F_{min} = 0$, $F_{max} = 52.2$ N, (iv) both 4×10^{-3} m/s

Q.16 (a) $\frac{d^2H^2S}{2\rho g} = 32$ Kg*f* – m , (b) $\frac{1}{2}$ $SH^2(1-d)^2 = 2$ Kg*f* –m

Q.17 $\frac{163}{36}$ cm, $\frac{388}{36}$ cm Q.18 $t = \frac{12\sqrt{14}}{\sqrt{15}-\sqrt{14}}$ Q.19 $\frac{\rho g R}{2}$

Q.20 2 sec., 1 sec Q.21 1/90π Q.22 b/3

Q.23 (a) 80cm, 5cm; (b) 300sec. Q.24 $2\sqrt{hH}$, 3m³ Q.25 $h = \frac{mg + 4sa}{\rho_w a^2 g}$

EXERCISE # III

Q.1 500 Pa

Q.2 (a)(i) $P = \frac{5}{4}$ d, (ii) $p = P_0 + \frac{1}{4}(6H+L)dg$; (b)(i) $v = \sqrt{\frac{g}{2}(3H-4h)}$, (ii) $x = \sqrt{h(3H-4h)}$ (iii) $x_{max} = \frac{3}{4}H$

Q.3 (i) 10 m/s, (ii) 14.1 m/s, (iii) 2.5 hr Q.4 $w = \sqrt{\frac{3g}{2L}\left(\frac{d_2-d_1}{d_1}\right)}$

Q.5 (i) 0.2 m/s², (ii) $\sqrt{2g\frac{m_0}{A\rho}}$ Q.6 + 29625 J/m³, – 30000 J/m³

Q.7 C

Q.8 $m_{min} = \pi r^2 l\,(\sqrt{\rho\sigma} - \rho)$; if tilted then it's axis should become vertical. C.M. should be lower than centre of bouyancy. Q.9 A Q.10 D

Q.11 D Q.12 (a) 0, (b) h = 0.25 cm, (c) a= g/6 (upward)

Q.13 x = 2 m Q.14 $f = \frac{1}{2\pi}\sqrt{\frac{3g}{2R}}$ Q.15 C Q.16 $H = \frac{L^2\omega^2}{2g}$

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (PQRS & J)

QUESTION BANK ON

FLUID MECHANICS

Time Limit : 2 Siting Each of 90 minutes. duration approx.

QUESTION BANK ON FLUID MECHANICS

There are 58 questions in this question bank.

Q.1 Two cubes of size 1.0 m sides, one of relative density 0.60 and another of relative density = 1.15 are connected by weightless wire and placed in a large tank of water. Under equilibrium the lighter cube will project above the water surface to a height of

(A) 50 cm (B) 25 cm (C) 10 cm (D) zero

Q.2 A rectangular tank is placed on a horizontal ground and is filled with water to a height H above the base. A small hole is made on one vertical side at a depth D below the level of the water in the tank. The distance x from the bottom of the tank at which the water jet from the tank will hit the ground is

(A) $2\sqrt{D(H-D)}$ (B) $2\sqrt{DH}$ (C) $2\sqrt{D(H+D)}$ (D) $\frac{1}{2}\sqrt{DH}$

Q.3 A beaker is filled in with water is accelerated a m/s^2 in +x direction. The surface of water shall make on angle

(A) $\tan^{-1}(a/g)$ backwards (B) $\tan^{-1}(a/g)$ forwards

(C) $\cot^{-1}(g/a)$ backwards (D) $\cot^{-1}(g/a)$ forwards

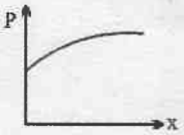
Q.4 A jet of water with cross section of 6 cm^2 strikes a wall at an angle of 60° to the normal and rebounds elastically from the wall without losing energy. If the velocity of the water in the jet is 12 m/s, the force acting on the wall is

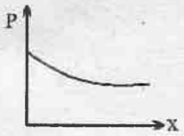
(A) 0.864 Nt (B) 86.4 Nt (C) 72 Nt (D) 7.2 Nt

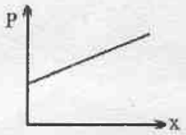
Q.5 The vertical limbs of a U shaped tube are filled with a liquid of density ρ upto a height h on each side. The horizontal portion of the U tube having length 2h contains a liquid of density 2ρ. The U tube is moved horizontally with an accelerator g/2 parallel to the horizontal arm. The difference in heights in liquid levels in the two vertical limbs, at steady state will be

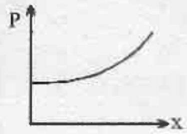
(A) $\frac{2h}{7}$ (B) $\frac{8h}{7}$ (C) $\frac{4h}{7}$ (D) None of these

Q.6 The cross sectional area of a horizontal tube increases along its length linearly, as we move in the direction of flow. The variation of pressure, as we move along its length in the direction of flow (x-direction), is best depicted by which of the following graphs

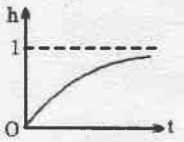
(A) 

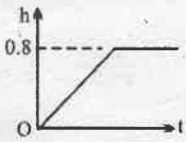
(B) 

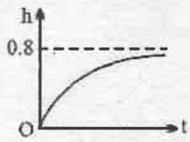
(C) 

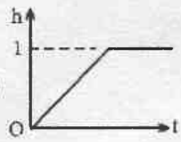
(D) 

Q.7 A cylindrical tank of height 1 m and cross section area A = 4000 cm^2 is initially empty when it is kept under a tap of cross sectional area 1 cm^2. Water starts flowing from the tap at t = 0, with a speed = 2 m/s. There is a small hole in the base of the tank of cross-sectional area 0.5 cm^2. The variation of height of water in tank (in meters) with time t is best depicted by

(A) 

(B) 

(C) 

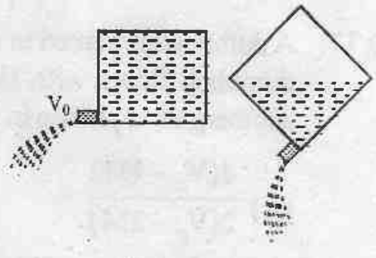
(D) 

Q.8 A bucket contains water filled upto a height = 15 cm. The bucket is tied to a rope which is passed over a frictionless light pulley and the other end of the rope is tied to a weight of mass which is half of that of the (bucket + water). The water pressure above atmosphere pressure at the bottom is

(A) 0.5 kPa (B) 1 kPa

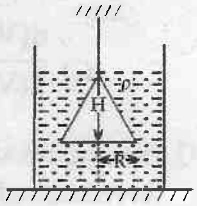
(C) 5 kPa (D) None of these

Q.9 A cubical box of wine has a small spout located in one of the bottom corners. When the box is full and placed on a level surface, opening the spout results in a flow of wine with a initial speed of v_0 (see figure). When the box is half empty, someone tilts it at 45° so that the spout is at the lowest point (see figure). When the spout is opened the wine will flow out with a speed of



(A) v_0 (B) $v_0/2$ (C) $v_0/\sqrt{2}$ (D) $v_0/\sqrt[4]{2}$

Q.10 A cone of radius R and height H, is hanging inside a liquid of density ρ by means of a string as shown in the figure. The force, due to the liquid acting on the slant surface of the cone is



(A) $\rho\pi gHR^2$ (B) $\pi\rho HR^2$ (C) $\frac{4}{3}\pi\rho gHR^2$ (D) $\frac{2}{3}\pi\rho gHR^2$

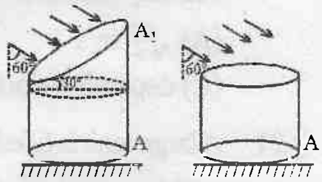
Q.11 A cuboidal piece of wood has dimensions a, b and c. Its relative density is d. It is floating in a large body of water such that side a is vertical. It is pushed down a bit and released. The time period of SHM executed by it is :

(A) $2\pi\sqrt{\frac{abc}{g}}$ (B) $2\pi\sqrt{\frac{g}{da}}$ (C) $2\pi\sqrt{\frac{bc}{dg}}$ (D) $2\pi\sqrt{\frac{da}{g}}$

Q.12 Water is flowing steadily through a horizontal tube of nonuniform cross-section. If the pressure of water is 4×10^4 N/m^2 at a point where cross-section is 0.02 m^2 and velocity of flow is 2 m/s, what is pressure at a point where cross-section reduces to 0.01 m^2.

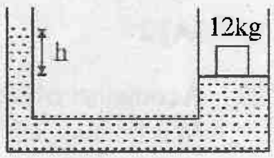
(A) 1.4×10^4 N/m^2 (B) 3.4×10^4 N/m^2 (C) 2.4×10^{-4} N/m^2 (D) none of these

Q.13 A vertical cylindrical container of base area A and upper cross-section area A_1 making an angle 30° with the horizontal is placed in an open rainy field as shown near another cylindrical container having same base area A. The ratio of rates of collection of water in the two containers will be



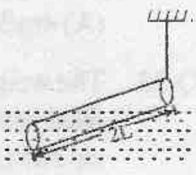
(A) $2/\sqrt{3}$ (B) $4/\sqrt{3}$ (C) 2 (D) None

Q.14 The area of cross-section of the wider tube shown in figure is 800 cm^2. If a mass of 12 kg is placed on the massless piston, the difference in heights h in the level of water in the two tubes is :



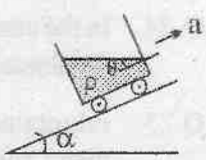
(A) 10 cm (B) 6 cm (C) 15 cm (D) 2 cm

Q.15 A slender homogeneous rod of length $2L$ floats partly immersed in water, being supported by a string fastened to one of its ends, as shown. The specific gravity of the rod is 0.75. The length of rod that extends out of water is :



(A) L (B) $\frac{1}{2}$ L (C) $\frac{1}{4}$ L (D) 3 L

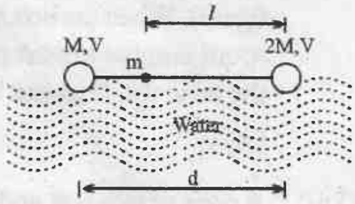
Q.16 A fluid container is containing a liquid of density ρ is accelerating upward with acceleration a along the inclined place of inclination α as shown. Then the angle of inclination θ of free surface is :



(A) $\tan^{-1}\left[\frac{a}{g\cos\alpha}\right]$ (B) $\tan^{-1}\left[\frac{a+g\sin\alpha}{g\cos\alpha}\right]$

(C) $\tan^{-1}\left[\frac{a-g\sin\alpha}{g(1+\cos\alpha)}\right]$ (D) $\tan^{-1}\left[\frac{a-g\sin\alpha}{g(1-\cos\alpha)}\right]$

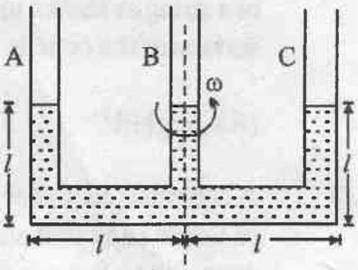
Q.17 A dumbbell is placed in water of density ρ. It is observed that by attaching a mass m to the rod, the dumbbell floats with the rod horizontal on the surface of water and each sphere exactly half submerged as shown in the figure. The volume of the mass m is negligible. The value of length l is



(A) $\frac{d(V\rho - 3M)}{2(V\rho - 2M)}$ (B) $\frac{d(V\rho - 2M)}{2(V\rho - 3M)}$

(C) $\frac{d(V\rho + 2M)}{2(V\rho - 3M)}$ (D) $\frac{d(V\rho - 2M)}{2(V\rho + 3M)}$

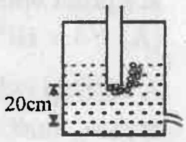
Q.18 Figure shows a three arm tube in which a liquid is filled upto levels of height l. It is now rotated at an angular frequency ω about an axis passing through arm B. The angular frequency ω at which level of liquid in arm B becomes zero.



(A) $\sqrt{\frac{2g}{3l}}$ (B) $\sqrt{\frac{g}{l}}$ (C) $\sqrt{\frac{3g}{l}}$ (D) $\sqrt{\frac{3g}{2l}}$

Q.19 Two bodies having volumes V and 2V are suspended from the two arms of a common balance and they are found to balance each other. If larger body is immersed in oil (density $d_1 = 0.9$ gm/cm^3) and the smaller body is immersed in an unknown liquid, then the balance remain in equilibrium. The density of unknown liquid is given by :
(A) 2.4 gm/cm^3 (B) 1.8 gm/cm^3 (C) 0.45 gm/cm^3 (D) 2.7 gm/cm^3

Q.20 A tube is attached as shown in closed vessel containing water. The velocity of water coming out from a small hole is :



(A) $\sqrt{2}$ m/s (B) 2 m/s
(C) depends on pressure of air inside vessel (D) None of these

Q.21 A large tank is filled with water to a height H. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to H/η, $(\eta > 1)$ and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is :
(A) 2 (B) 3 (C) 4 (D) $2\sqrt{2}$

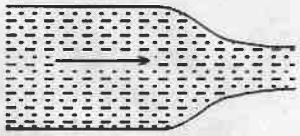
Q.22 A container of large surface area is filled with liquid of density ρ. A cubical block of side edge a and mass M is floating in it with four-fifth of its volume submerged. If a coin of mass m is placed gently on the top surface of the block is just submerged. M is
(A) 4m/5 (B) m/5 (C) 4m (D) 5m

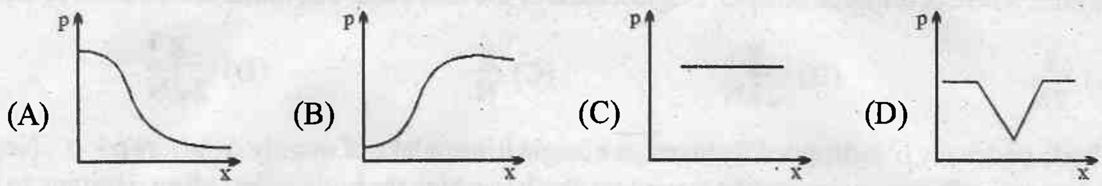
Q.23 The weight of an empty balloon on a spring balance is w_1. The weight becomes w_2 when the balloon is filled with air. Let the weight of the air itself be w. Neglect the thickness of the balloon when it is filled with air. Also neglect the difference in the densities of air inside & outside the balloon. Then :
(A) $w_2 = w_1$ (B) $w_2 = w_1 + w$ (C) $w_2 < w_1 + w$ (D) $w_2 > w_1$

Q.24 In the case of a fluid, Bernoulli's theorem expresses the application of the principle of conservation of :
(A) linear momentum (B) energy (C) mass (D) angular momentum

Q.25 Fountains usually seen in gardens are generated by a wide pipe with an enclosure at one end having many small holes. Consider one such fountain which is produced by a pipe of internal diameter 2 cm in which water flows at a rate 3 ms^{-1}. The enclosure has 100 holes each of diameter 0.05 cm. The velocity of water coming out of the holes ids (in ms^{-1}):
(A) 0.48 (B) 96 (C) 24 (D) 48

Q.26 Water flows through a frictionless duct with a cross-section varying as shown in figure. Pressure p at points along the axis is represented by

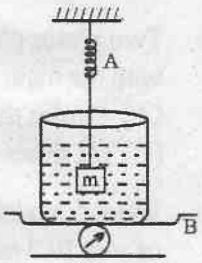




Q.27 A boy carries a fish in one hand and a bucket(not full) of water in the other hand . If he places the fish in the bucket, the weight now carried by him (assume that water does not spill) :
(A) is less than before (B) is more than before
(C) is the same as before (D) depends upon his speed

Q.28 A cubical block of wood of edge 10cm and mass 0.92kg floats on a tank of water with oil of rel. density 0.6 to a depth of 4cm above water. When the block attains equilibrium with four of its sides edges vertical
(A) 1cm of it will be above the free surface of oil.
(B) 5cm of it will be under water.
(C) 2cm of it will be above the common surface of oil and water.
(D) 8cm of it will be under water.

Q.29 The spring balance A reads 2 kg with a block m suspended from it. A balance B reads 5 kg when a beaker with liquid is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid in the beaker as shown in the figure in this situation:



(A) the balance A will read more than 2 kg
(B) the balance B will read more than 5 kg
(C) the balance A will read less than 2 kg and B will read more than 5 kg
(D) the balances A and B will read 2 kg and 5 kg respectively.

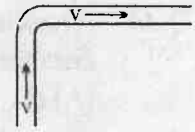
Q.30 An open cubical tank was initially fully filled with water. When the tank was accelerated on a horizontal plane along one of its side it was found that one third of volume of water spilled out. The acceleration was
(A) g/3 (B) 2g/3 (C) 3g/2 (D) None

Q.31 A cork of density $0.5 gcm^{-3}$ floats on a calm swimming pool. The fraction of the cork's volume which is under water is
(A) 0% (B) 25% (C) 10% (D) 50%

Q.32 A cylindrical vessel filled with water upto the height H becomes empty in time t_0 due to a small hole at the bottom of the vessel. If water is filled to a height 4H it will flow out in time
(A) t_0 (B) $4t_0$ (C) $8t_0$ (D) $2t_0$

Q.33 A cylindrical vessel open at the top is 20cm high and 10cm in diameter. A circular hole whose cross-sectional area 1 cm^2 is cut at the centre of the bottom of the vessel. Water flows from a tube above it into the vessel at the rate 100 cm^3s^{-1}. The height of water in the vessel under steady state is (Take $g=1000 cms^{-2}$)
(A) 20 cm (B) 15 cm (C) 10 cm (D) 5 cm

Q.34 A fire hydrant delivers water of density ρ at a volume rate L. The water travels vertically upward through the hydrant and then does 90° turn to emerge horizontally at speed V. The pipe and nozzle have uniform crosssection throughout. The force exerted by the water on the corner of the hydrant is



(A) ρVL (B) zero (C) 2ρVL (D) $\sqrt{2}\rho VL$

Q.35 A vertical tank, open at the top, is filled with a liquid and rests on a smooth horizontal surface. A small hole is opened at the centre of one side of the tank. The area of cross-section of the tank is N times the area of the hole, where N is a large number. Neglect mass of the tank itself. The initial acceleration of the tank is

(A) $\frac{g}{2N}$ (B) $\frac{g}{\sqrt{2N}}$ (C) $\frac{g}{N}$ (D) $\frac{g}{2\sqrt{N}}$

Q.36 A body of density ρ' is dropped from rest at a height h into a lake of density ρ, where $\rho > \rho'$. Neglecting all dissipative forces, calculate the maximum depth to which the body sinks before returning to float on the surface.

(A) $\frac{h}{\rho-\rho'}$ (B) $\frac{h\rho'}{\rho}$ (C) $\frac{h\rho'}{\rho-\rho'}$ (D) $\frac{h\rho}{\rho-\rho'}$

Q.37 A Newtonian fluid fills the clearance between a shaft and a sleeve. When a force of 800N is applied to the shaft, parallel to the sleeve, the shaft attains a speed of 1.5 cm/sec. If a force of 2.4 kN is applied instead, the shaft would move with a speed of
(A) 1.5 cm/sec (B) 13.5 cm/sec (C) 4.5 cm/sec (D) None

Q.38 A solid metallic sphere of radius r is allowed to fall freely through air. If the frictional resistance due to air is proportional to the cross-sectional area and to the square of the velocity, then the terminal velocity of the sphere is proportional to which of the following?
(A) r^2 (B) r (C) $r^{3/2}$ (D) $r^{1/2}$

Q.39 Two water pipes P and Q having diameters 2×10^{-2}m and 4×10^{-2}m, respectively, are joined in series with the main supply line of water. The velocity of water flowing in pipe P is
(A) 4 times that of Q (B) 2 times that of Q
(C) 1/2 times of that of Q (D) 1/4 times that of Q

Q.40 Water flows into a cylindrical vessel of large cross-sectional area at a rate of 10^{-4} m^3/s. It flows out from a hole of area 10^{-4} m^2, which has been punched through the base. How high does the water rise in the vessel?
(A) 0.075 m (B) 0.051 m (C) 0.031 m (D) 0.025 m

Q.41 Two cylinders of same cross-section and length L but made of two material of densities d_1 and d_2 are cemented together to form a cylinder of length 2L. The combination floats in a liquid of density d with a length L/2 above the surface of the liquid. If $d_1 > d_2$ then:
(A) $d_1 > \frac{3}{4}d$ (B) $\frac{d}{2} > d_1$ (C) $\frac{d}{4} > d_1$ (D) $d < d_1$

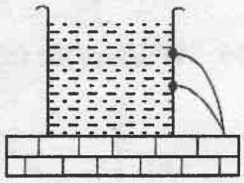
Q.42 There is a horizontal film of soap solution. On it a thread is placed in the form of a loop. The film is pierced inside the loop and the thread becomes a circular loop of radius R. If the surface tension of the loop be T, then what will be the tension in the thread?
(A) $\pi R^2/T$ (b) $\pi R^2 T$ (C) $2\pi RT$ (D) 2RT

Q.43 Some liquid is filled in a cylindrical vessel of radius R. Let F_1 be the force applied by the liquid on the bottom of the cylinder. Now the same liquid is poured into a vessel of uniform square crss-section of side R. Let F_2 be the force applied by the liquid on the bottom of this new vessel. Then:
(A) $F_1 = \pi F_2$ (B) $F_1 = \frac{F_2}{\pi}$ (C) $F_1 = \sqrt{\pi}F_2$ (D) $F_1 = F_2$

Q.44 A tank is filled up to a height 2H with a liquid and is placedon a platform of height H from the ground. The distance x from the ground where a small hole is punched to get the maximum range R is:
(A) H (B) 1.25 H (C) 1.5 H (D) 2 H

Q.45 A container, whose bottom has round holes with diameter 0.1 mm is filled with water. The maximum height in cm upto which water can be filled without leakage will be what?
Surface tension = 75×10^{-3} N/m and g = 10 m/s^2:
(A) 20 cm (B) 40 cm (C) 30 cm (D) 60 cm

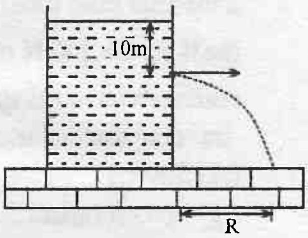
Q.46 In a cylindrical vessel containing liquid of density ρ, there are two holes in the side walls at heights of h_1 and h_2 respectively such that the range of efflux at the bottom of the vessel is same. The height of a hole, for which the range of efflux would be maximum, will be



(A) $h_2 - h_1$ (B) $h_2 + h_1$
(C) $\frac{h_2 - h_1}{2}$ (D) $\frac{h_2 + h_1}{2}$

Q.47 A piece of steel has a weight W in air, W_1 when completely immersed in water and W_2 when completely immersed in an unknown liquid. The relative density (specific gravity) of liquid is:
(A) $\frac{W - W_1}{W - W_2}$ (B) $\frac{W - W_2}{W - W_1}$ (C) $\frac{W_1 - W_2}{W - W_1}$ (D) $\frac{W_1 - W_2}{W - W_2}$

Q.48 A large tank is filled with water (density = 10^3 kg/m^3). A small hole is made at a depth 10 m below water surface. The range of water issuing out of the hole is R on ground. What extra pressure must be applied on the water surface so that the range becomes 2R (take 1 atm = 10^5 Pa and g = 10 m/s^2):

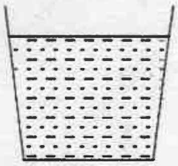


(A) 9 atm (B) 4 atm
(C) 5 atm (D) 3 atm

Q.49 Two drops of same radius are falling through air with steady velocity of v cm/s. If the two drops coalesce, what would be the terminal velocity?
(A) 4 v (B) $(4)^{1/3}$ v (C) 2 v (D) 64 v

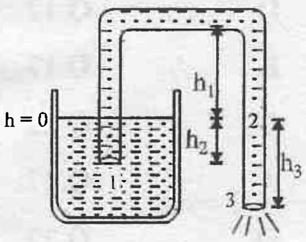
Q.50 A ball of relative density 0.8 falls into water from a height of 2m. The depth to which the ball will sink is (neglect viscous forces):
(A) 8 m (B) 2 m (C) 6 m (D) 4 m

Q.51 A liquid of mass 1 kg is filled in a flask as shown in figure. The force exerted by the flask on the liquid is (g = 10 m/s^2):



(A) 10 N (B) greater than 10N (C) less than 10N (D) zero

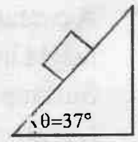
Q.52 Figure shows a siphon. Choose the wrong statement:



(A) Siphon works when $h_3 > 0$
(B) Pressure at point 2 is $P_2 = P_0 - \rho g h_3$
(C) Pressure at point 3 is P_0
(D) None of the above
(P_0 = atmospheric pressure)

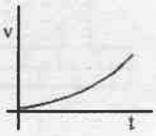
Q.53 If two soap bubbles of different radii are connected by a tube,
(A) air flows from the bigger bubble to the smaller bubble till the sizes become equal
(B) air flows from bigger bubble to the smaller bubble till the sizes are interchanged
(C) air flows from the smaller bubble to the bigger
(D) there is no flow of air.

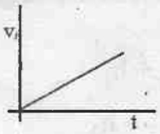
Q.54 A cubical block of side 'a' and density 'ρ' slides over a fixed inclined plane with constant velocity 'v'. There is a thin film of viscous fluid of thickness 't' between the plane and the block. Then the coefficient of viscosity of the thin film will be

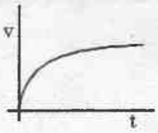


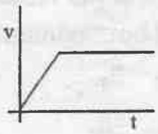
(A) $\frac{3\rho a g t}{5v}$ (B) $\frac{4\rho a g t}{5v}$ (C) $\frac{\rho a g t}{v}$ (D) none of these

Q.55 Which of the following graphs best represents the motion of a raindrop?

(A) 

(B) 

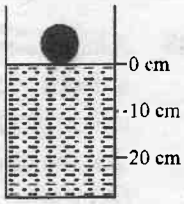
(C) 

(D) 

Q.56 Two soap bubbles with radii r and $(r_1 > r_2)$ come in contact. Their common surface has a radius of curvature r.

(A) $r = \frac{r_1 + r_2}{2}$ (B) $r = \frac{r_1 r_2}{r_1 - r_2}$ (C) $r = \frac{r_1 r_2}{r_1 + r_2}$ (D) $r = \sqrt{r_1 r_2}$

Q.57 A spherical ball of density ρ and radius 0.003m is dropped into a tube containing a viscous fluid filled up to the 0 cm mark as shown in the figure. Viscosity of the fluid = 1.260 N.m^{-2} and its density $\rho_L = \rho/2 = 1260$ kg.m^{-3}. Assume the ball reaches a terminal speed by the 10 cm mark. The time taken by the ball to traverse the distance between the 10 cm and 20 cm mark is



(A) 500 μs (B) 50 ms (C) 0.5 s (D) 5 s

(g = acceleration due to gravity = 10 ms^{-2})

Q.58 A sphere is dropped under gravity through a fluid of viscosity η. If the average acceleration is half of the initial acceleration, the time to attain the terminal velocity is (ρ = density of sphere ; r = radius)

(A) $\frac{4\rho r^2}{9\eta}$ (B) $\frac{9\rho r^2}{4\eta}$ (C) $\frac{4\rho r}{9\eta}$ (D) $\frac{9\rho r}{4\eta}$

ANSWER KEY

Q.1	B	Q.2	A	Q.3	A, C	Q.4	B	Q.5	B
Q.6	A	Q.7	C	Q.8	B	Q.9	D	Q.10	D
Q.11	D	Q.12	B	Q.13	C	Q.14	C	Q.15	A
Q.16	B	Q.17	B	Q.18	C	Q.19	B	Q.20	B
Q.21	C	Q.22	C	Q.23	A, C	Q.24	B	Q.25	D
Q.26	A	Q.27	C	Q.28	C, D	Q.29	B, C	Q.30	B
Q.31	D	Q.32	D	Q.33	D	Q.34	D	Q.35	C
Q.36	C	Q.37	C	Q.38	D	Q.39	A	Q.40	B
Q.41	A	Q.42	D	Q.43	D	Q.44	C	Q.45	C
Q.46	D	Q.47	B	Q.48	D	Q.49	B	Q.50	A
Q.51	A	Q.52	D	Q.53	C	Q.54	A	Q.55	C
Q.56	B	Q.57	D	Q.58	A				

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PHYSICS

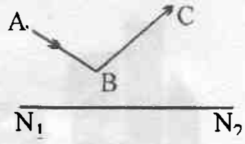
XII (ALL)

QUESTION BANK ON

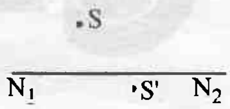
GEOMETRICAL OPTICS

SHORT QUESTIONS

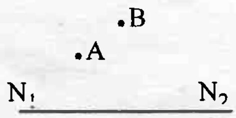
Q.1 The position of the optical axis N_1N_2, the path of ray AB incident upon a lens and the refracted ray BC are known (figure). Find by construction the position of the main foci of the lens.



Q.2 Point S' is the image of a point source of light S in a spherical mirror whose optical axis is N_1N_2 (figure). Find by construction the position of the centre of curvature and its focus.



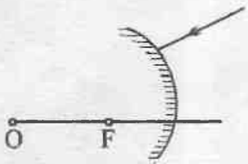
Q.3 The positions of optical axis N_1N_2 of a spherical mirror, the source and the image are known (figure). Find by construction the positions of the centre of the curvature, its focus and the pole for the cases:
(a) A – source, B – image; (b) B – source, A – image



Q.4 The layered lens shown in figure is made of two kinds of glass. What image will be produced by this lens with a point source arranged on the optical axis? Disregard the reflection of light on the boundary between layers.

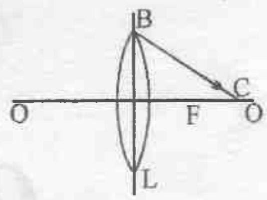


Q.5 A ray of light falls on a convex mirror, as shown in figure. Trace the path of the ray further.



Q.6 A double convex lens of focal length f lies between a source of light and a screen. The distance between the source of light and the screen is less than $4f$. It is known that in these conditions it is not possible to obtain an image of the source on the screen, whatever the position of the lens. How can an image of the source be obtained on the screen with quite simple means and without moving either lens or screen?

Q.7 In figure is depicted the path of a ray of light BC after refraction in a double convex lens L of principal focus F and of principal axis OO. Find by construction the path of this ray before reaching the lens.



Q.8 Where should a point source of light lie along the principal axis of a converging lens so that it is impossible to see the source and its image simultaneously from any point?

Q.9 A disk whose plane surface are parallel is cut as shown in figure (i), then the lenses so obtained are moved apart. What will happen to a beam of parallel rays falling on to the resulting system:
(a) from the side of the converging lens (figure ii),
(b) form the side of the diverging lens (figure iii)?
Consider the cases when the distance between the lenses is less than the focal length and when it is greater than the focal length.

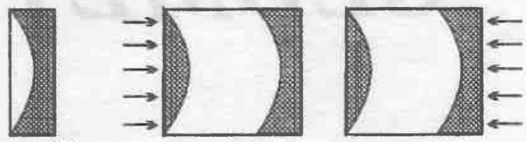


figure (i) figure (ii) figure (iii)

Q.10 What will happen if a plane mirror is placed in the path of a converging beam ?

Q.11 Can a prism transmit rays at all angles of incidence?

Q.12 Why is it difficult to shoot a fish swimming in water ?

Q.13 A light ray passes through the interface between two transparent media . Under what condition will the angle of refraction be equal to the angle of incidence ?

Q.14 In what case will a bi-convex lens be diverging ?

Q.15 Is the width of a beam increased or decreased in going from air to water?

Q.16 Ordinary paper becomes transparent when it is oiled. Explain.

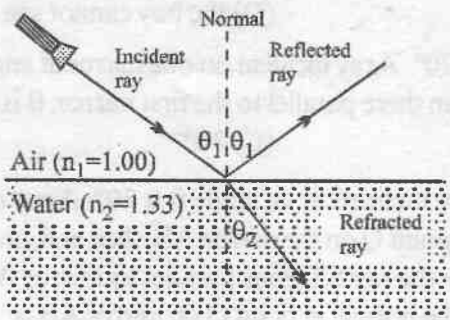
Q.17 If there are scratches on the lens of a camera, they do not appear on a photograph taken with the camera. Explain. Do the scratches affect the photograph at all?

Q.18 Concave mirrors are used as shaving mirrors. Why? Should such mirrors have short or long focal lengths?

Q.19 A sign painted on a store window is reversed when viewed from inside the store. If a person inside the store views the reversed sign in a plane mirror, does the sign appear as it would when viewed from outside the store? (Try it by writing some letters on a transparent sheet of paper and then holding the back side of the paper up to a mirror.) Explain.

Q.20 If you stand between two parallel plane mirrors, you see an infinite number of images of yourself. This occurs because an image in one mirror is reflected in the other mirror to produce another image, which is then re-reflected, and so forth. The multiple images are equally spaced. Suppose that you are facing a convex mirror, with a plane mirror behind you. Describe what you would see and comment about the spacing between any multiple images. Explain your reasoning.

Q.21 In the figure, suppose that a layer of oil were added on top of the water. The angle θ_1 at which the incident light travels through the air remains the same. Assuming that light still enters the water, does the angle of refraction at which it does so change because of the presence of the oil? Explain.



Q.22 A beam of blue light is propagating in glass. When the light reaches the boundary between the glass and the surrounding air, the beam is totally reflected back into the glass. However, red light with the same angle of incidence is not totally reflected, and some of the light is refracted into the air. Why do these two colors behave differently?

Q.23 To a swimmer under water, objects look blurred and out of focus. However, when the swimmer wears goggles that keep the water away from the eyes, the objects appear sharp and in focus. Why do goggles improve a swimmer's underwater vision?

ONLY ONE OPTION IS CORRECT.

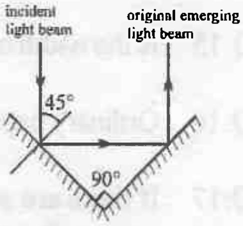
Take approx. 2 minutes for answering each question.

Q.1 A person runs with a speed u towards a bicycle moving away from him with speed v. The person approaches his image in the plane mirror fixed at the rear of bicycle with a speed of

(A) u – v (B) u – 2v

(C) 2u – v (D) 2(u – v)

Q.2 A beam of light strikes one mirror of a right angle mirror assembly at an angle of incidence 45° as shown in the figure. The right angle mirror assembly is rotated such that the angle of incidence becomes 60°. Which of the following statement is correct about the emerging light beam.



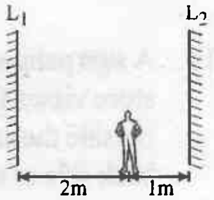
(A) It will move through an angle of 15° w.r.t. the original emerging beam.

(B) It will move through an angle of 30° w.r.t. the original emerging beam.

(C) It will move through an angle 45° w.r.t. the original beam.

(D) It will emerge parallel to the original emerging beam.

Q.3 Two mirrors labelled L_1 for left mirror and L_2 for right mirror in the figure are parallel to each other and 3.0 m apart. A person standing 1.0 m from the right mirror (L_2) looks into this mirror and sees a series of images. The second nearest image seen in the right mirror is situated at a distance :



(A) 2.0 m from the person (B) 4.0 m from the person

(C) 6.0 m from the person (D) 8.0 m from the person.

Q.4 The reflection surface of a plane mirror is vertical. A particle is projected in a vertical plane which is also perpendicular to the mirror. The initial velocity of the particle is 10 m/s and the angle of projection is 60°. The point of projection is at a distance 5 m from the mirror. The particle moves towards the mirror. Just before the particle touches the mirror the velocity of approach of the particle and its image is :

(A) 10 m/s (B) 5 m/s (C) $10\sqrt{3}$ m/s (D) $5\sqrt{3}$ m/s

Q.5 A boy of height 1.5 m with his eye level at 1.4 m stands before a plane mirror of length 0.75 m fixed on the wall. The height of the lower edge of the mirror above the floor is 0.8 m. Then :

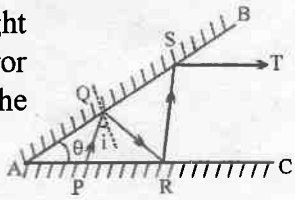
(A) the boy will see his full image (B) the boy cannot see his hair

(C) the boy cannot see his feet (D) the boy cannot see neither his hair nor his feet.

Q.6 Two plane mirrors are inclined at 70°. A ray incident on one mirror at angle θ after reflection falls on the second mirror and is reflected from there parallel to the first mirror, θ is :

(A) 50° (B) 45° (C) 30° (D) 55°

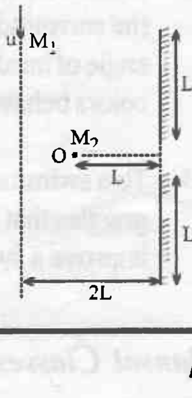
Q.7 Two plane mirror AB and AC are inclined at an angle θ = 20°. A ray of light starting from point P is incident at point Q on the mirroe AB, then at R on mirror AC and again on S on AB finally the ray ST goes parallel to mirror Ac. The angle iwhich the ray makes with the normal at point Q on mirror AB is



(A) 20° (B) 30°

(C) 40° (D) 60°

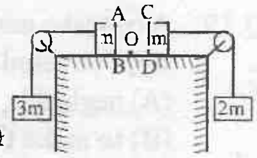
Q.8 Two plane mirrors of length L are separated by distance L and a man M_2 is standing at distance L from the connecting line of mirrors as shown in figure. A man M_1 is walking is a straight line at distance 2 L parallel to mirrors at speed u, then man M_2 at O will be able to see image of M_1 for total time:



(A) $\frac{4L}{u}$ (B) $\frac{3L}{u}$ (C) $\frac{6L}{u}$ (D) $\frac{9L}{u}$

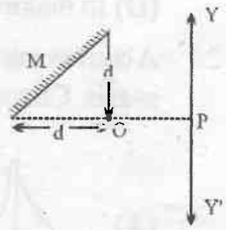
Q.9 Two plane mirrors are placed parallel to each other at a distance L apart. A point object O is placed between them, at a distance L / 3 from one mirror. Both mirrors form multiple images. The distance between any two images cannot be
(A) 3L / 2 (B) 2L / 3 (C) 2L (D) None

Q.10 Two blocks each of mass m lie on a smooth table. They are attached to two other masses as shown in the figure. The pulleys and strings are light. An object O is kept at rest on the table. The sides AB & CD of the two blocks are made reflecting. The acceleration of two images formed in those two reflecting surfaces w.r.t. each other is:



(A) 5g / 6 (B) 5g / 3 (C) g / 3 (D) 17g / 6

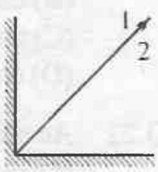
Q.11 As shown in the figure a particle is placed at O in front of a plane mirror M. A man at P can move along path PY and PY' then which of the following is true



(A) For all point on PY man can see the image of O
(B) For all point on PY' man can see the image, but for no point on PY he can see the image of O
(C) For all point on PY' he can see the image but on PY he can see the image only upto distance d.
(D) He can see the image only upto a distance d on either side of P.

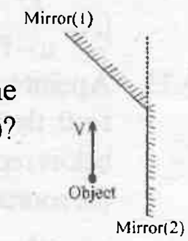
Q.12 A man of height 'h' is walking away from a street lamp with a constant speed 'v'. The height of the street lamp is 3h. The rate at which of the length of the man's shadow is increasing when he is at a distance 10h from the base of the street lamp is :
(A) v/2 (B) v/3 (C) 2v (D) v/6

Q.13 A two eyed man is looking at the junction of two large mutually perpendicular mirrors from a far off distance. Assume no reflection to occur from the edge. Then if both the eyes are open



(A) The eye 1 of man can see image of both eye 1 and eye 2.
(B) The eye 1 can see image of eye 1 only and eye 2 see image of eye 2 only.
(C) The eye 1 can see image of eye 2 only and eye 2 can see image of eye one only.
(D) All the above statements are false.

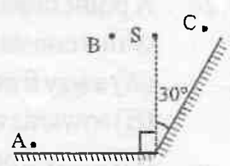
Q.14 In the diagram shown, all the velocities are given with respect to earth. What is the relative velocity of the image in mirror (1) with respect to the image in the mirror (2)? The mirror (1) forms an angle β with the vertical.



(A) 2Vsin2β (B) 2Vsinβ (C) 2V / sin2β (D) none

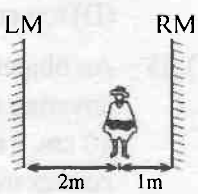
Q.15 A point object is kept in front of a plane mirror. The plane mirror is doing SHM of amplitude 2 cm. The plane mirror moves along the x-axis and x-axis is normal to the mirror. The amplitude of the mirror is such that the object is always infront of the mirror. The amplitude of SHM of the image is
(A) zero (B) 2 cm (C) 4 cm (D) 1 cm

Q.16 A point source of light S is placed in front of two large mirrors as shown. Which of the following observers will see only one image of S?



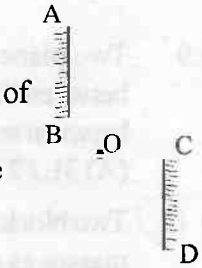
(A) only A (B) only C
(C) Both A and C (D) Both B and C

Q.17 Two mirrors, labeled LM for left mirror and RM for right mirror in the adjacent figure, are parallel to each other and 3.0 m apart. A person standing 1.0 m from the right mirror (RM) looks into this mirror and sees a series of images. How far from the person is the second closest image seen in the right mirror (RM)?



(A) 10.0 m (B) 4.0 m
(C) 6.0 m (D) 8.0 m

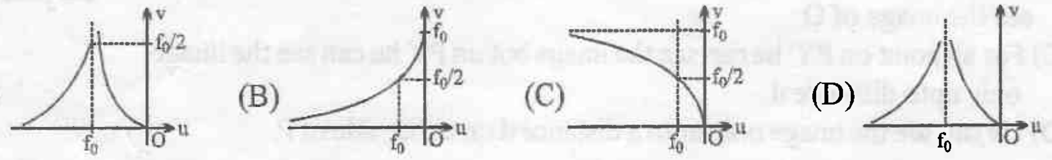
Q.18 Two mirrors AB and CD are arranged along two parallel lines. The maximum number of images of object O that can be seen by any observer is



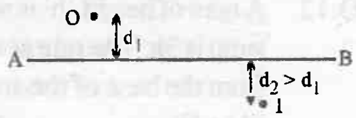
(A) One (B) Two (C) Four (D) Infinite

Q.19 A concave mirror is used to form image of the Sun on a white screen. If the lower half of the mirror were covered with an opaque card, the effect on the image on the screen would be
(A) negligible
(B) to make the image less bright than before
(C) to make the upper half of the image disappear
(D) to make the lower half of the image disappear

Q.20 A convex mirror of focal length 'f' is placed at the origin with its reflecting surface towards the negative x-axis. Choose the correct graphs between 'v' and 'u' for u < 0.



Q.21 In the figure shown, the image of a real object is formed at point I. AB is the principal axis of the mirror. The mirror must be :

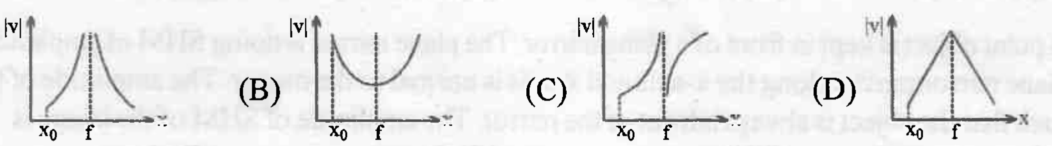


(A) concave & placed towards right I
(B) concave & placed towards left of I
(C) convex and placed towards right of I
(D) convex & placed towards left of I.

Q.22 An infinitely long rod lies along the axis of a concave mirror of focal length f. The near end of the rod is at a distance u > f from the mirror. Its image will have a length

(A) $\frac{f^2}{u-f}$ (B) $\frac{uf}{u-f}$ (C) $\frac{f^2}{u+f}$ (D) $\frac{uf}{u+f}$

Q.23 A point source is situated at a distance x < f from the pole of the concave mirror of focal length f. At time t = 0, the point source starts moving away from the mirror with constant velocity. Which of the graphs below represents best, variation of image distance | v | with the distance x between the pole of mirror and the source.

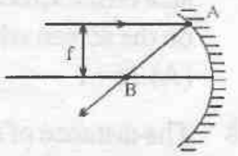


Q.24 A point object is between the Pole and Focus of a concave mirror, and moving away from the mirror with a constant speed. Then, the velocity of the image is :
(A) away from mirror and increasing in magnitude
(B) towards mirror and increasing in magnitude
(C) away from mirror and decreasing in magnitude
(D) towards mirror and decreasing in magnitude

Q.25 An object is placed in front of a convex mirror at a distance of 50 cm. A plane mirror is introduced covering the lower half of the convex mirror. If the distance between the object and the plane mirror is 30 cm, it is found that there is no gap between the images formed by the two mirrors. The radius of the convex mirror is :
(A) 12.5 cm (B) 25 cm (C) 50 cm (D) 100 cm

Q.26 A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror and C its centre of curvature. A point object is placed at C. It has a real image, also located at C (a condition called auto-collimation). If the mirror is now filled with water, the image will be:
(A) real, and will remain at C
(B) real, and located at a point between C and ∞
(C) virtual, and located at a point between C and O.
(D) real, and located at a point between C and O.

Q.27 A ray of light is incident on a concave mirror. It is parallel to the principal axis and its height from principal axis is equal to the focal length of the mirror. The ratio of the distance of point B to the distance of the focus from the centre of curvature is (AB is the reflected ray)

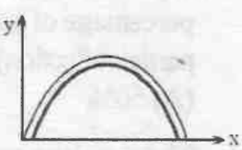


(A) $\frac{2}{\sqrt{3}}$ (B) $\frac{\sqrt{3}}{2}$ (C) $\frac{2}{3}$ (D) $\frac{1}{2}$

Q.28 A luminous point object is moving along the principal axis of a concave mirror of focal length 12 cm towards it. When its distance from mirror is 20 cm its velocity is 4 cm/s. The velocity of the image in cm/s at that instant is :
(A) 6 towards the mirror (B) 6 away from the mirror
(C) 9 away from the mirror (D) 9 towards the mirror

Q.29 When an object is placed at a distance of 25 cm from a concave mirror, the magnification is m_1. The object is moved 15 cm farhter away with respect to the earlier position, and the magnification becomes m_2. If $m_1/m_2 = 4$ the focal length of the mirror is (Assume image is real m_1, m_2 are numerical values)
(A) 10 cm (B) 30 cm (C) 15 cm (D) 20 cm

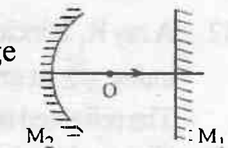
Q.30 A reflecting surface is represented by the equation $Y = \frac{2L}{\pi}\,\text{sm}\left(\frac{\pi x}{L}\right)$, $0 < x < L$. A ray travelling horizontally becomes vertical after reflection. The coordinates of the point (s) where this ray is incident is



(A) $\left(\frac{L}{4}, \frac{\sqrt{2}\,L}{\pi}\right)$ (B) $\left(\frac{L}{3}, \frac{\sqrt{3}\,L}{\pi}\right)$ (C) $\left(\frac{3L}{4}, \frac{\sqrt{2}\,L}{\pi}\right)$ (D) $\left(\frac{2L}{3}, \frac{\sqrt{3}\,L}{\pi}\right)$

Q.31 The origin of x and y coordinates is the pole of a concave mirror of focal length 20 cm. The x-axis is the optical axis with x > 0 being the real side of mirror. A point object at the point (25 cm, 1 cm) is moving with a velocity 10 cm/s in positive x-direction. The velocity of the image in cm/s is approximately
(A) – 80 i + 8 j (B) 160 i + 8 j (C) – 160 i + 8 j (D) 160 i – 4 j

Q.32 In the figure shown if the object 'O' moves towards the plane mirror, then the image I (which is formed after successive reflections from M_1 & M_2 respectively) will move:



(A) towards right (B) towards left (C) with zero velocity (D) cannot be determined

Q.33 All of the following statements are correct except (for real object):
(A) the magnification produced by a convex mirror is always less thenor equal to one
(B) a virtual, erect, same sized image can be obtained using a plane mirror
(C) a virtual, erect, magnified image can be formed using a concave mirror
(D) a real, inverted, same sized image can be formed using a convex mirror.

Q.34 The distance of an object from the pole of a concave mirror is equal to its radius of curvature. The image must be :
(A) real (B) inverted (C) same sized (D) erect

Q.35 A straight line joining the object point and image point is always perpendicular to the mirror
(A) if mirror is plane only (B) if mirror is concave only
(C) if mirror is convex only (D) irrespective of the type of mirror.

Q.36 A concave mirror forms a real image three times larger than the object on a screen. Object and screen are moved until the image becomes twice the size of object. If the shift of object is 6 cm. The shift of the screen & focal length of mirror are
(A) 36 cm, 36cm (B) 36cm, 16cm (C) 72cm, 36cm (D) none of these

Q.37 A point source of light is 60 cm from a screen and is kept at the focus of a concave mirror which reflects light on the screen. The focal length of the mirror is 20 cm. The ratio of average intensities of the illumination on the screen when the mirror is present and when the mirror is removed is :
(A) 36 : 1 (B) 37 : 1 (C) 49 : 1 (D) 10:1

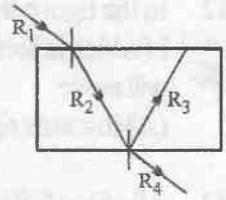
Q.38 The distance of a real object from the focus of a convex mirror of radius of curvature 'a' is 'b'. Then the distance of the image from the focus is
(A) $\frac{b^2}{4a}$ (B) $\frac{a}{b^2}$ (C) $\frac{a^2}{4b}$ (D) none of these

Q.39 Choose the correct statement(s) related to the motion of object and its image in the case of mirrors
(A) Object and its image always move along normal w.r.t. mirror in opposite directions
(B) Only in the case of convex mirror, it may happen that the object and its image move in the same direction
(C) Only in the case of concave mirror, it may happen that the object and its image move in the same direction
(D) Only in case of plane mirrors, object and its image move in opposite directions

Q.40 A point source of light is placed at a distance h below the surface of a large deep lake. What is the percentage of light energy that escapes directly from the water surface is μ of the water = 4/3? (neglect partial reflection)
(A) 50% (B) 25% (C) 20% (D) 17%

Q.41 The x-z plane separates two media A and B with refractive indices μ_1 and μ_2 respectively. A ray of light travels from A to B. Its directions in the two media are given by the unit vectors, $\vec{r}_A = a\hat{i} + b\hat{j}$ & $\vec{r}_B = \alpha\hat{i} + \beta\hat{j}$ respectively where $\hat{i}$ & $\hat{j}$ are unit vectors in the x and y directions. Then
(A) $\mu_1 a = \mu_2 \alpha$ (B) $\mu_1 \alpha = \mu_2 a$ (C) $\mu_1 b = \mu_2 \beta$ (D) $\mu_1 \beta = \mu_2 b$

Q.42 A ray R_1 is incident on the plane surface of the glass slab (kept in air) of refractive index $\sqrt{2}$ at angle of incident equal to the critical angle for this air glass system. The refracted ray R_2 undergoes partial reflection & refraction at the other surface. The angle between reflected ray R_3 and the refracted ray R_4 at that surface is :

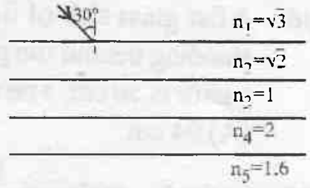


(A) 45° (B) 135°
(C) 105° (D) 75°

Q.43 A ray of light from a denser medium strike a rarer medium. The angle of reflection is r and that of refraction is r'. The reflected and refracted rays make an angle of 90° with each other. The critical angle will be :
(A) $\sin^{-1}(\tan r)$ (B) $\tan^{-1}(\sin r)$
(C) $\sin^{-1}(\tan r')$ (D) $\tan^{-1}(\sin r')$

Q.44 A tiny air bubble in a glass slab ($\mu = 1.5$) appears from one side to be 6 cm from the glass surface and from other side, 4 cm. The thickness of the glass slab is
(A) 10 cm (B) 6.67 cm (C) 15 cm (D) one of these

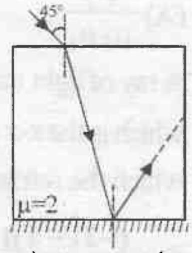
Q.45 In the figure shown the angle made by the light ray with the normal in the medium of refractive index 1 is :



(A) 30° (B) 60°
(C) 90° (D) None of these

Q.46 A plane glass slab is placed over various coloured letters. The letter which appears to be raised the least is
(A) red (B) yellow (C) violet (D) green

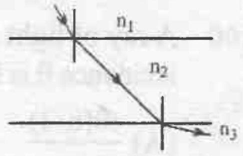
Q.47 Bottom face of the glass cube is silvered as shown. A ray of light incident on top face of the cube as shown. Find the deviation of the ray when it comes out of the glass cube :



(A) 0 (B) 90°
(C) 180° (D) 270°

Q.48 A ray of light is incident upon an air/water interface (it passes from air into water) at an angle of 45°. Which of the following quantities change as the light enters the water?
(I) wavelength (II) frequency
(III) speed of propagation (IV) direction of propagation
(A) I, III only (B) III, IV only (C) I, II, IV only (D) I, III, IV only

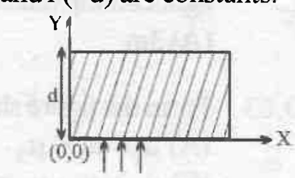
Q.49 The figure shows the path of a ray of light as it passes through three different materials with refractive indices n_1, n_2 and n_3. The figure is drawn to scale. The refractive indices of the material satisfy relation



(A) $n_3 < n_2 < n_1$ (B) $n_3 < n_1 < n_2$
(C) $n_2 < n_1 < n_3$ (D) $n_1 < n_3 < n_2$

Q.50 The critical angle for glass to air refraction is least for which colour ?
(A) orange (B) blue (C) violet (D) red

Q.51 A long rectangular slab of transparent medium is placed on a horizontal table with its length parallel to the x-axis and width parallel to the y-axis as shown in the figure. A ray of light travelling in air makes a normal incidence on the slab. The refractive index μ of the medium varies as $\frac{\mu_0}{1-(x/r)}$, where μ_0 and r (>d) are constants.



(A) The incident ray travels in parabolically inside the slab.
(B) The incident ray travels in hyperbolic path inside the slab.
(C) The incident ray travels in circular path inside the slab.
(D) The incident ray travels in elliptical path inside the slab.

Q.52 A ray of light travels from an optical denser medium to rarer medium. The critical angle for the two media is C. The maximum possible deviation of the refracted light ray can be :
(A) $\pi - C$ (B) 2C (C) $\pi - 2C$ (D) $\frac{\pi}{2} - C$

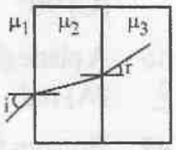
Q.53 A microscope is focused on a point object and then its objective is raised through a height of 2cm. If a glass slab of refractive index 1.5 is placed over this point object such that it is focused again, the thickness of the glass slab is :
(A) 6 cm (B) 3 cm (C) 2 cm (D) 1.5 cm

Q.54 A paraxial beam of light is converging towards a point P on the screen. A plane parallel sheet of glass of thickness t and refractive index μ is introduced in the path of beam. The convergence point is shifted by :
(A) t (1 – 1/μ) away (B) t (1 + 1/μ) away (C) t (1 – 1/μ) nearer (D) t (1 + 1/μ) nearer

Q.55 A bird is flying 3 m above the surface of water. If the bird is diving vertically down with speed = 6 m/s, his apparent velocity as seen by a stationary fish underwater is :
(A) 8 m/s (B) 6 m/s (C) 12 m/s (D) 4 m/s

Q.56 A flat glass slab of thickness 6 cm and index 1.5 is placed in front of a plane mirror. An observer is standing behind the glass slab and looking at the mirror. The actual distance of the observer from the mirror is 50 cm. The distance of his image from himself, as seen by the observer is :
(A) 94 cm (B) 96 cm (C) 98 cm (D) 100 cm

Q.57 In the figure shown $\frac{\sin i}{\sin r}$ is equal to :



(A) $\frac{\mu_2^2}{\mu_3 \mu_1}$ (B) $\frac{\mu_3}{\mu_1}$ (C) $\frac{\mu_3 \mu_1}{\mu_2^2}$ (D) none

Q.58 A ray of light moving along the unit vector $(-\mathbf{i} - 2\mathbf{j})$ undergoes refraction at an interface of two media, which is the x-z plane. The refractive index for $y > 0$ is 2 while for $y < 0$, it is $\sqrt{5}/2$. The unit vector along which the refracted ray moves is :
(A) $\frac{(-3\hat{i} - 5\hat{j})}{\sqrt{34}}$ (B) $\frac{(-4\hat{i} - 3\hat{j})}{5}$ (C) $\frac{(-3\hat{i} - 4\hat{j})}{5}$ (D) None of these

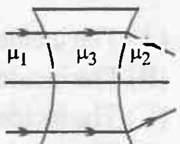
Q.59 An object is placed 20 cm in front of a 4 cm thick plane mirror. The image of the object finally is formed at 45 cm from the object itself. The refractive index of the material of the unpolished side of the mirror is (considering near normal incidence)
(A) 1.5 (B) 1.6 (C) 1.4 (D) none of these

Q.60 A ray of light is incident on a parallel slab of thickness t and refractive index n. If the angle of incidence θ is small than the displacement in the incident and emergent ray will be :
(A) $\frac{t\theta(n-1)}{n}$ (B) $\frac{t\theta}{n}$ (C) $\frac{t\theta n}{n-1}$ (D) none

Q.61 A ray of light is incident at an angle of 75° into a medium having refractive index μ. The reflected and the refracted rays are found to suffer equal deviations in opposite direction μ equals
(A) $\frac{\sqrt{3}+1}{\sqrt{3}-1}$ (B) $\frac{\sqrt{3}+1}{2}$ (C) $\frac{2\sqrt{2}}{\sqrt{3}+1}$ (D) None of these

Q.62 A small source of light is 4m below the surface of a liquid of refractive index 5/3. In order to cut off all the light coming out of liquid surface, minimum diameter of the disc placed on the surface of liquid is :
(A) 3m (B) 4m (C) 6m (D) ∞

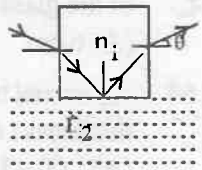
Q.63 From the figure shown establish a relation between, μ_1, μ_2, μ_3.



(A) $\mu_1 < \mu_2 < \mu_3$ (B) $\mu_3 < \mu_2$; $\mu_3 = \mu_1$
(C) $\mu_3 > \mu_2$; $\mu_3 = \mu_1$ (D) None of these

Q.64 The critical angle of light going from medium A to medium B is θ. The speed of light in medium A is v. The speed of light in medium B is :
(A) $\frac{v}{\sin\theta}$ (B) $v \sin\theta$ (C) $v \cot\theta$ (D) $v \tan\theta$

Q.65 A cubical block of glass of refractive index n_1 is in contact with the surface of water of refractive index n_2. A beam of light is incident on vertical face of the block (see figure). After refraction, a total internal reflection at the base and refraction at the opposite vertical face, the ray emerges out at an angle θ. The value of θ is given by :

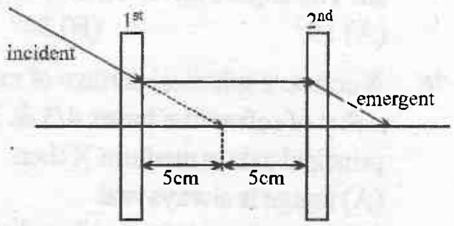


(A) $\sin\theta < \sqrt{n_1^2 - n_2^2}$ (B) $\tan\theta < \sqrt{n_1^2 - n_2^2}$
(C) $\sin\theta < \frac{1}{\sqrt{n_1^2 - n_2^2}}$ (D) $\tan\theta < \frac{1}{\sqrt{n_1^2 - n_2^2}}$

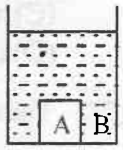
Q.66 The flat bottom of cylinder tank is silvered and water ($\mu = 4/3$) is filled in the tank upto a height h. A small bird is hovering at a height 3h from the bottom of the tank. When a small hole is opened near the bottom of the tank, the water level falls at the rate of 1 cm/s. The bird will perceive that his image's velocity is :
(A) 0.5 cm/s upward (B) 1 cm/s downwards
(C) 0.5 cm/s downwards (D) none of these

Q.67 A vertical pencil of rays comes from bottom of a tank filled with a liquid. When it is accelerated with an acceleration of 7.5 m/s^2, the ray is seen to be totally reflected by liquid surface. What is minimum possible refractive index of liquid?
(A) slightly greater than 4/3 (B) slightly greater than 5/3
(C) slightly greater than 1.5 (D) slightly greater than 1.75

Q.68 Look at the ray diagram shown, what will be the focal length of the 1st and the 2nd lens, if the incident light ray passes without any deviation?
(A) –5cm and –10cm
(B) +5cm and +10cm
(C) –5cm and +5cm
(D) +5cm and +5cm



Q.69 A parallel sided block of glass of refractive index 1.5 which is 36 mm thick rests on the floor of a tank which is filled with water (refractive index = 4/3). The difference between apparent depth of floor at A & B when seen from vertically above is equal to
(A) 2 mm (B) 3 mm (C) 4 mm (D) none of these

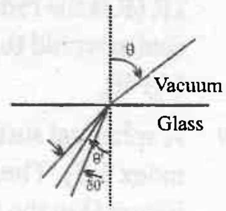


Q.70 A ray of light is incident on one face of a transparent slab of thickness 15 cm. The angle of incidence is 60°. If the lateral displacement of the ray on emerging from the parallel plane is $5\sqrt{3}$ cm, the refractive index of the material of the slab is
(A) 1.414 (B) 1.532 (C) 1.732 (D) none

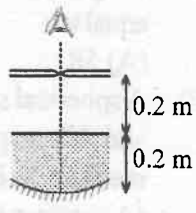
Q.71 A beam of light has a small wavelength spread $\delta\lambda$ about a central wavelength λ. The beam travels in vaccum until it enters a glass plate at an angle θ relative to the normal to the plate, as shown in figure. The index of refraction of the glass is given by $n(\lambda)$. The angular spread $\delta\theta'$ of the refracted beam is given by

(A) $\delta\theta' = \left|\frac{1}{n}\delta\lambda\right|$ (B) $\delta\theta' = \left|\frac{dn(\lambda)}{d\lambda}\delta\lambda\right|$

(C) $\delta\theta' = \left|\frac{\tan\theta'}{n}\frac{dn(\lambda)}{d\lambda}\delta\lambda\right|$ (D) $\delta\theta' = \left|\frac{\sin\theta}{\sin\theta'}\frac{\delta\lambda}{\lambda}\right|$

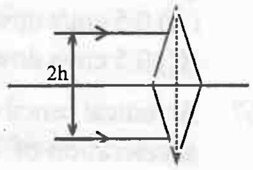


Q.72 When a pin is moved along the principal axis of a small concave mirror, the image position coincides with the object at a point 0.5 m from the mirror, refer figure. If the mirror is placed at a depth of 0.2 m in a transparent liquid, the same phenomenon occurs when the pin is placed 0.4 m from the mirror. The refractive index of the liquid is
(A) 6/5 (B) 5/4 (C) 4/3 (D) 3/2



Q.73 A light ray is incident on a transparent sphere of index = $\sqrt{2}$, at an angle of incidence = 45°. What is the deviation of a tiny fraction of the ray, which enters the sphere, undergoes two internal reflections, and then refracts out into air ?
(A) 270° (B) 240° (C) 120° (D) 180°

Q.74 Two identical thin isosceles prisms of refracting angle 'A' and refractive index μ are placed with their bases touching each other. Two parallel rays of light are incident on this system as shown. The distance of the point where the rays converge from the prism is :



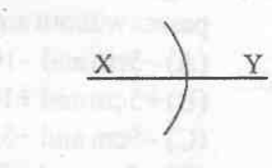
(A) $\frac{h}{\mu A}$ (B) $\frac{h}{A}$

(C) $\frac{h}{(\mu-1)A}$ (D) $\frac{\mu h}{(\mu-1)A}$

Q.75 A ray of sunlight enters a spherical water droplet (n = 4/3) at an angle of incidence 53° measured with respect to the normal to the surface. It is reflected from the back surface of the droplet and re-enters into air. The angle between the incoming and outgoing ray is [Take sin 53° = 0.8]

(A) 15° (B) 34° (C) 138° (D) 30°

Q.76 A concave spherical surface of radius of curvature 10cm separates two medium x & y of refractive index 4/3 & 3/2 respectively. If the object is placed along principal axis in medium X then



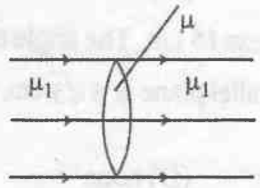
(A) image is always real

(B) image is real if the object distance is greater than 90cm

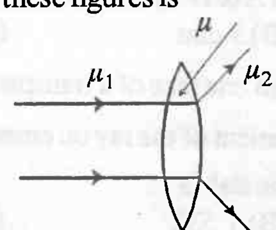
(C) image is always virtual

(D) image is virtual if the object distance is less than 90cm

Q.77 The correct conclusion that can be drawn from these figures is



(a)



(b)

(A) $\mu_1 < \mu$ but $\mu < \mu_2$ (B) $\mu_1 > \mu$ but $\mu < \mu_2$ (C) $\mu_1 = \mu$ but $\mu < \mu_2$ (D) $\mu_1 = \mu$ but $\mu_2 < \mu$

Q.78 A fish is near the centre of a spherical water filled (μ = 4/3) fish bowl. A child stands in air at a distance 2R (R is the radius of curvature of the sphere) from the centre of the bowl. At what distance from the centre would the child nose appear to the fish situated at the centre :

(A) 4R (B) 2R (C) 3R (D) 4R

Q.79 A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object P placed in air is found to have a real image Q in the glass. The lime PQ cuts the surface at the point O, and PO = OQ. The distance PO is equal to :

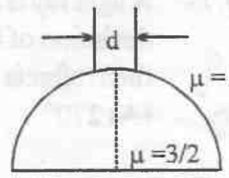
(A) 5R (B) 3 R (C) 2 R (D) 1.5 R

Q.80 A spherical surface of radius of curvature 10 cm separates two media X and Y of refractive indices 3/2 and 4/3 respectively. Centre of the spherical surface lies in denser medium. An object is placed in medium X. For image to be real, the object distance must be

(A) greater than 90 cm (B) less than 90 cm.

(C) greater than 80 cm (D) less than 80 cm.

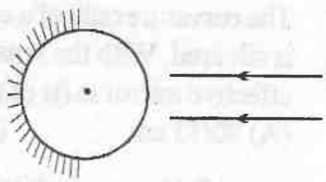
Q.81 A beam of diameter 'd' is incident on a glass hemisphere as shown. If the radius of curvature of the hemisphere is very large in comparison to d, then the diameter of the beam at the base of the hemisphere will be:



(A) $\frac{3}{4}$ d (B) d (C) $\frac{d}{3}$ (D) $\frac{2}{3}$ d

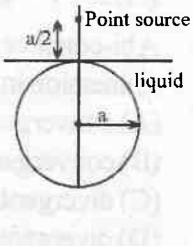
Q.82 A concave spherical refracting surface separates two media glass and air ($\mu_{glass} = 1.5$). If the image is to be real at what minimum distance u should the object be placed in glass if R is the radius of curvature?
(A) $u > 3R$ (B) $u > 2R$ (C) $u < 2R$ (D) $u < R$

Q.83 A glass sphere of index 1.5 and radius 40 cm has half its hemispherical surface silvered. The point where a parallel beam of light, coming along a diameter, will focus (or appear to) after coming out of sphere, will be:



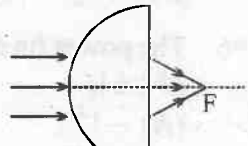
(A) 10 cm to the left of centre (B) 30 cm to the left of centre
(C) 50 cm to the left of centre (D) 60 cm to the left of centre

Q.84 An opaque sphere of radius a is just immersed in a transparent liquid as shown in figure. A point source is placed on the vertical diameter of the sphere at a distance a/2 from the top of the sphere. One ray originating from the point source after refraction from the air liquid interface forms tangent to the sphere. The angle of refraction for that particular ray is 30°. The refractive index of the liquid is



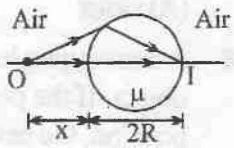
(A) $\frac{2}{\sqrt{3}}$ (B) $\frac{3}{\sqrt{5}}$ (C) $\frac{4}{\sqrt{5}}$ (D) $\frac{4}{\sqrt{7}}$

Q.85 A paraxial beam is incident on a glass (n = 1.5) hemisphere of radius R = 6 cm in air as shown. The distance of point of convergence F from the plane surface of hemisphere is



(A) 12 cm (B) 5.4 cm
(C) 18 cm (D) 8 cm

Question No. 86 to 89(4 questions)
The figure, shows a transparent sphere of radius R and refractive index μ. An object O is placed at a distance x from the pole of the first surface so that a real image is formed at the pole of the exactly opposite surface.



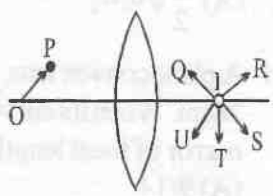
Q.86 If x = 2R, then the value of μ is
(A) 1.5 (B) 2 (C) 3 (D) none of these

Q.87 If x = ∞, then the value of μ is
(A) 1.5 (B) 2 (C) 3 (D) none of these

Q.88 If an object is placed at a distance R from the pole of first surface, then the real image is formed at a distance R from the pole of the second surface. The refractive index μ of the sphere is given by
(A) 1.5 (B) 2 (C) $\sqrt{2}$ (D) none of these

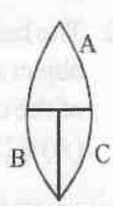
Q.89 In **previous problem**, if the refractive index of the sphere is varied, then the position x of the object and its image from the respective poles will also vary. Identify the correct statement.
(A) If the value of μ increases the value of x decreases
(B) If the value of μ becomes equal to unity, then x tends to infinity
(C) The value of μ must not be less than 1
(D) All the above

Q.90 A point object O moves from the principal axis of a converging lens in a direction OP. I is the image of O, will move initially in the direction



(A) IQ (B) IR
(C) IS (D) IU

Q.91 A thin symmetric double - convex lens of power P is cut into three parts A, B and C as shown. The power of



(A) A is P (B) A is 2P
(C) B is P (D) B is P/4

Q.92 A lens behaves as a converging lens in air but a diverging lens in water, then the refractive index(μ) of its material is
(A) $\mu > 4/3$ (B) $\mu > 3/2$ (C) $\mu < 4/3$ (D) $\mu < 3/2$

Q.93 The curvature radii of a concavo-convex glass lens are 20 cm and 60 cm. The convex surface of the lens is silvered. With the lens horizontal, the concave surface is filled with water. The focal length of the effective mirror is (μ of glass = 1.5, μ of water = 4/3)
(A) 90/13 cm (B) 80/13 cm (C) 20/3 cm (D) 45/8 cm

Q.94 A parallel beam of white light falls on a convex lens. Images of blue, red and green light are formed on other side of the lens at distances x, y and z respectively from the pole of the lens. Then :
(A) $x > y > z$ (B) $x > z > y$ (C) $y > z > x$ (D) None

Q.95 A bi-concave glass lens having refractive index 1.5 has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a
(A) convergent lens of focal length 3.5 R
(B) convergent lens of focal length 3.0 R
(C) divergent lens of focal length 3.5 R
(D) divergent lens of focal length 3.0 R

Q.96 The power (in diopters) of an equiconvex lens with radii of curvature of 10 cm and refractive index of 1.6 is :
(A) -12 (B) $+12$ (C) $+1.2$ (D) -1.2

Q.97 The focal length of a lens is greatest for which colour?
(A) violet (B) red (C) yellow (D) green

Q.98 A converging lens forms an image of an object on a screen. The image is real and twice the size of the object. If the positions of the screen and the object are interchanged, leaving the lens in the original position, the new image size on the screen is
(A) twice the object size
(B) same as the object size
(C) half the object size
(D) can't say as it depends on the focal length of the lens.

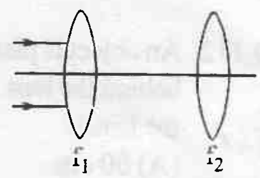
Q.99 An object is placed in front of a symmetrical convex lens with refractive index 1.5 and radius of curvature 40 cm. The surface of the lens further away from the object is silvered. Under auto-collimation condition, the object distance is
(A) 20 cm (B) 10 cm (C) 40 cm (D) 5 cm

Q.100 When the object is at distances u_1 and u_2 the images formed by the same lens are real and virtual respectively and of the same size. Then focal length of the lens is :
(A) $\frac{1}{2}\sqrt{u_1u_2}$ (B) $\frac{1}{2}(u_1 + u_2)$ (C) $\sqrt{u_1u_2}$ (D) $2(u_1 + u_2)$

Q.101 A planoconvex lens, when silvered at its plane surface is equivalent to a concave mirror of focal length 28cm. When its curved surface is silvered and the plane surface not silvered, it is equivalent to a concave mirror of focal length 10cm, then the refractive index of the material of the lens is :
(A) 9/14 (B) 14/9 (C) 17/9 (D) none

Q.102 The height of the image formed by a converging lens on a screen is 8cm. For the same position of the object and screen again an image of size 12.5cm is formed on the screen by shifting the lens. The height of the object :
(A) 625/32cm (B) 64/12.5cm (C) 10cm (D) none

Q.103 Parallel beam of light is incident on a system of two convex lenses of focal lengths $f_1 = 20$ cm and $f_2 = 10$ cm. What should be the distance between the two lenses so that rays after refraction from both the lenses pass undeviated :

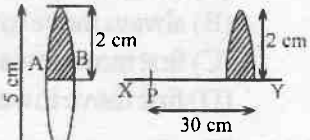


(A) 60 cm (B) 30 cm
(C) 90 cm (D) 40 cm

Q.104 A bi-concave symmetric lens made of glass has refractive index 1.5. It has both surfaces of same radius of curvature R. On immersion in a liquid of refractive index 1.25, it will behave as a
(A) Converging lens of focal length 2.5 R (B) Converging lens of focal length 2.0 R
(C) Diverging lens of focal length 4.5 R (D) None of these

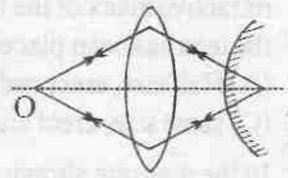
Q.105 A lateral object of height 0.5 cm is placed on the optical axis of bi-convex lens of focal length 80 cm, at an object distance = 60 cm. The image formed is :
(A) virtual, erect and 4 cm high (B) virtual, inverted and 2 cm high
(C) virtual, erect and 2 cm high (D) real, inverted and 2 cm high.

Q.106 A converging lens of focal length 20 cm and diameter 5 cm is cut along the line AB. The part of the lens shown shaded in the diagram is now used to form an image of a point P placed 30 cm away from it on the line XY. Which is perpendicular to the plane of the lens. The image of P will be formed.



(A) 0.5 cm above XY (B) 1 cm below XY
(C) on XY (D) 1.5 cm below XY

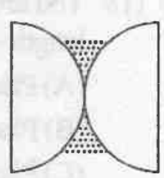
Q.107 A object is placed at a distance of 15 cm from a convex lens of focal length 10 cm. On the other side of the lens, a convex mirror is placed at its focus such that the image formed by the combination coincides with the object itself. The focal length of the convex mirror is



(A) 20 cm (B) 10 cm (C) 15 cm (D) 30 cm

Q.108 A thin lens of focal length f and its aperture has a diameter d. It forms an image of intensity I. Now the central part of the aperture upto diameter (d/2) is blocked by an opaque paper. The focal length and image intensity would change to
(A) f/2, I/2 (B) f, I/4 (C) 3f/4, I/2 (D) f, 3I/4

Q.109 Two planoconvex lenses each of focal length 10 cm & refractive index 3/2 are placed as shown. In the space left, water (R.I = 4/3) is filled. The whole arrangement is in air. The optical power of the system is (in diopters) :



(A) 6.67 (B) − 6.67
(C) 33.3 (D) 20

Q.110 A concave mirror is placed on a horizontal surface and two thin uniform layers of different transparent liquids (which do not mix or interact) are formed on the reflecting surface. The refractive indices of the upper and lower liquids are μ_1 and μ_2 respectively. The bright point source at a height 'd' (d is very large in comparison to the thickness of the film) above the mirror coincides with its own final image. The radius of curvature of the reflecting surface therefore is

(A) $\frac{\mu_1 d}{\mu_2}$ (B) $\mu_1\mu_2 d$ (C) $\mu_1 d$ (D) $\mu_2 d$

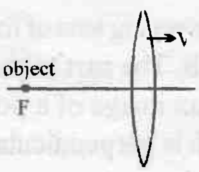
Q.111 An object is moving towards a converging lens on its axis. The image is also found to be moving towards the lens. Then, the object distance 'u' must satify
(A) $2f < u < 4f$ (B) $f < u < 2f$ (C) $u > 4f$ (D) $u < f$

Q.112 An object is placed in front of a thin convex lens of focal length 30 cm and a plane mirror is placed 15 cm behind the lens. If the final image of the object coincides with the object, the distance of the object from the lens is
(A) 60 cm (B) 30 cm (C) 15 cm (D) 25 cm

Q.113 Two point sources P and Q are 24 cm apart. Where should a convex lens of focal length 9 cm be placed in between them so that the images of both sources are formed at the same place?
(A) 3 cm from P (B) 15 cm from Q (C) 9 cm from Q (D) 18 cm from P

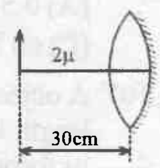
Q.114 If a concave lens is placed in path of converging rays real image will be produced if the distance of the pole from the point of convergence of incident rays lies between (f = magnitude of focal length of lens)
(A) 0 and f (B) f and 2f
(C) 2f and infinity (D) f and infinity

Q.115 A point object is kept at the first focus of a convex lens. If the lens starts moving towards right with a constant velocity, the image will



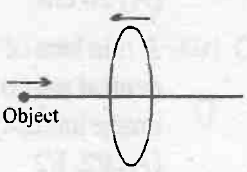
(A) always move towards right
(B) always move towards left
(C) first move towards right & then towards left.
(D) first move towards left & then towards right.

Q.116 The diagram shows a silvered equiconvex lens. An object of length 1 cm has been placed in the front of the lens. What will be the final image properties? The refractive index of the lens is μ and the refractive index of the medium in which the lens has been placed is 2μ. Both the surface have the radius R.



(A) Half size, erect and virtual (B) same size, erect and real
(C) same size, erect and virtual (D) none

Q.117 In the diagram shown, the lens is moving towards the object with a velocity V m/s and the object is also moving towards the lens with the same speed. What speed of the image with respect to earth when the object is at a distance 2f from the lens? (f is the focal length.)



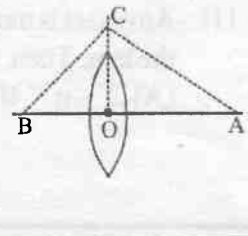
(A) 2V (B) 4V (C) 3V (D) V

Q.118 You are given two lenses, a converging lens with focal length +10 cm and a diverging lens with focal length – 20 cm. Which of the following would produce a virtual image that is larger than the object?
(A) Placing the object 5cm from the converging lens.
(B) Placing the object 15cm from the converging lens.
(C) Placing the object 25cm from the converging lens.
(D) Placing the object 15cm from the diverging lens.

Q.119 A screen is placed 90 cm from a object. The image of an object on the screen is formed by a convex lens at two different locations separated by 20 cm. The focal length of the lens is
(A) 18 cm (B) 21.4 cm (C) 60 cm (D) 85.6 cm

Q.120 In the **above problem**, if the size of the image formed at the positions are 6 cm and 3 cm, then the highest of the object is
(A) 4.2 cm (B) 4.5 cm (C) 5 cm (D) none of these

Q.121 If an object is placed at A (OA>f); Where f is the focal length of the lens the image is found to be formed at B. A perpendicular is erected at o and C is chosen on it such that the angle ∠BCA is a right angle. Then the value of f will be



(A) AB/OC^2 (B) (AC)(BC)/OC
(C) OC^2/AB (D) (OC)(AB)/AC+BC

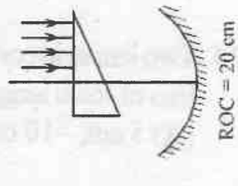
Q.122 One of the refractive surfaces of a prism of angle 30° is silvered. A ray of light incident at an angle of 60° retraces it path. The refractive index of the material of prism is :

(A) $\sqrt{2}$ (B) $\sqrt{3}$ (C) 3/2 (D) 2

Q.123 On an equilateral prism, it is observed that a ray strikes grazingly at one face and if refractive index of the prism is 2 then the angle of deviation is

(A) 60° (B) 120° (C) 30° (D) 90°

Q.124 A parallel beam of light is incident on the upper part of a prism of angle 1.8° and R.I. 3/2. The light coming out of the prism falls on a concave mirror of radius of curvature 20 cm. The distance of the point (where the rays are focused after reflection from the mirror) from the principal axis is :

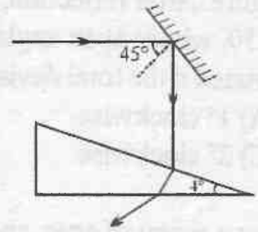


(A) 9 cm (B) 0.157 cm
(C) 0.314 cm (D) None of these

Q.125 The refractive index of a prism is, $\cot\frac{A}{2}$ where A = angle of prism. The angle of minimum deviation is (in degrees)

(A) 2A (B) 90 – A (C) 180 – 2A (D) 0

Q.126 A ray of light strikes a plane mirror at an angle of incidence 45° as shown in the figure. After reflection, the ray passes through a prism of refractive index 1.5, whose apex angle is 4°. The angle through which the mirror should be rotated if the total deviation of the ray is to be 90° is :



(A) 1° clockwise (B) 1° anticlockwise
(C) 2° clockwise (D) 2° anticlockwise

Q.127 The refracting angle of prism is 60° and the index of refraction is 1/2 relative to surrounding. The limiting angle of incidence of a ray that the will be transmitted through the prism is :

(A) 30° (B) 45° (C) 15° (D) 50°

Q.128 One face of a prism with a refracting angle of 30° is coated with silver. A ray incident on other face at an angle of 45° is refracted and reflected from the silvered coated face and retraces its path. The refractive index of the prism is :

(A) 2 (B) $\sqrt{3}$ (C) $\sqrt{3/2}$ (D) $\sqrt{2}$

Q.129 An equilateral prism deviates a ray through 40° for two angles of incidence differing by 20°. The possible angles of incidences are :

(A) 40°, 60° (B) 50°, 30° (C) 45°, 55° (D) 30°, 60°

Q.130 A beam of monochromatic light is incident at i = 50° on one face of an equilateral prism, the angle of emergence is 40°, then the angle of minimum deviation is :

(A) 30° (B) < 30° (C) < 30° (D) > 30°

Q.131 The dispersive powers of two lenses are 0.01 and 0.02. If focal length of one lens is + 10 cm, then what should the focal length of the second lens, so that they form an achromatic combination?

(A) Diverging lens having focal length 20 cm. (B) Converging lens having focal length 20 cm
(C) Diverging lens having focal length 10 cm. (D) Converging lens having focal length 10 cm

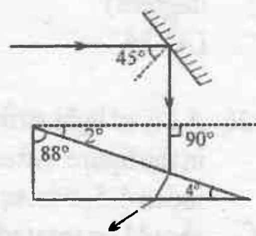
Q.132 A thin prism of angle 5° is placed at a distance of 10 cm from object. What is the distance of the image from object? (Given μ of prism = 1.5)
(A) $\frac{\pi}{8}$ cm (B) $\frac{\pi}{12}$ cm (C) $\frac{5\pi}{36}$ cm (D) $\frac{\pi}{7}$ cm

Q.133 A prism has a refractive index $\sqrt{\frac{3}{2}}$ and refracting angle 90°. Find the minimum deviation produced by prism.
(A) 40° (B) 45° (C) 30° (D) 49°

Q.134 Two lenses in contact made of materials with dispersive powers in the ratio 2 : 1, behaves as an achromatic lens of focal length 10 cm. The individual focal lengths of the lenses are:
(A) 5 cm, –10 cm (B) – 5 cm, 10 cm (C) 10 cm, – 20 cm (D) – 20 cm, 10 cm

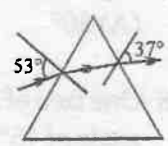
Q.135 R.I. of a prism is $\sqrt{\frac{7}{3}}$ and the angle of prism is 60°. The limiting angle of incidence of a ray that will be tansmitted through the prism is :
(A) 30° (B) 45° (C) 15° (D) 50°

Q.136 A ray of light strikes a plane mirror at an angle of incidence 45° as shown in the figure. After reflection, the ray passes through a prism of refractive index 1.50, whose apex angle is 4°. The angle through which the mirror should be rotated if the total deviation of the ray is to be 90° is
(A) 1° clockwise (B) 1° anticlockwise
(C) 2° clockwise (D) 2° anticlockwise

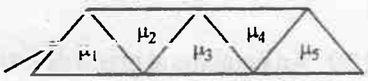


Q.137 For a prism of apex angle 45°, it is found that the angle of emergence is 45° for grazing incidence. Calculate the refractive index of the prism.
(A) $(2)^{1/2}$ (B) $(3)^{1/2}$ (C) 2 (D) $(5)^{1/2}$

Q.138 A ray incident at an angle 53° on a prism emerges at an angle at 37° as shown. If the angle of incidence is made 50°, which of the following is a possible value of the angle of emergence.
(A) 35° (B) 42° (C) 40° (D) 38°

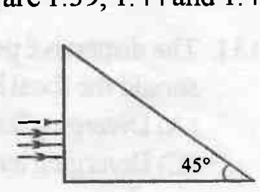


Q.139 The diagram shows five isosceles right angled prisms. A light ray incident at 90° at the first face emerges at same angle with the normal from the last face. Which of the following relations will hold regarding the refractive indices?



(A) $\mu_1^2 + \mu_3^2 + \mu_5^2 = \mu_2^2 + \mu_4^2$ (B) $\mu_1^2 + \mu_3^2 + \mu_5^2 = 1 + \mu_2^2 + \mu_4^2$
(C) $\mu_1^2 + \mu_3^2 + \mu_5^2 = 2 + \mu_2^2 + \mu_4^2$ (D) none

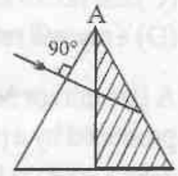
Q.140 A beam of light consisting of red, green and blue and is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will :
(A) separate part of the red color from the green and blue colors.
(B) separate part of the blue color from the red and green colours.
(C) separate all the three colors from the other two colors.
(D) not separate even partially any color from the other two colors.



Q.141 A certain prism is found to produce a minimum deviation of 38°. It produces a deviation of 44° when the angle of incidence is either 42° or 62°. What is the angle of incidencewhen it is undergoing minimum deviation?
(A) 45°
(B) 49°
(C) 40°
(D) 55°

Q.142 It is desired to make an achromatic combination of two lenses (L_1 & L_2) made of materials having dispersive powers ω_1 and ω_2 ($<\omega_1$). If the combination of lenses is converging then
(A) L_1 is converging
(B) L_2 is converging
(C) Power of L_1 is greater than the power of L_2
(D) None of these

Q.143 A ray of light is incident normally on the first refracting face of the prism of refracting angle A. The ray of light comes out at grazing emergence. If one half of the prism (shaded position) is knocked off, the same ray will



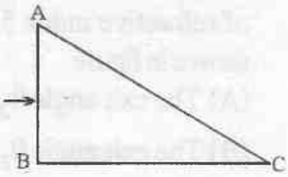
(A) emerge at an angle of emergence $\sin^{-1}\left(\frac{1}{2}\sec A/2\right)$
(B) not emerge out of the prism
(C) emerge at an angle of emergence $\sin^{-1}\left(\frac{1}{2}\sec A/4\right)$
(D) None of these

Q.144 An achromatic convergent doublet of two lens in contact has a power of + 2 D. The convex lens is power + 5 D. What is the ratio of the dispersive powers of the convergent and divergent lenses?
(A) 2 : 5
(B) 3 : 5
(C) 5 : 2
(D) 5 : 3

Q.145 Light ray is incident on a prism of angle A = 60° and refractive index $\mu = \sqrt{2}$. The angle of incidence at which the emergent ray grazes the surface is given by
(A) $\sin^{-1}\left(\frac{\sqrt{3}-1}{2}\right)$
(B) $\sin^{-1}\left(\frac{1-\sqrt{3}}{2}\right)$
(C) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$
(D) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$

Q.146 Two incident monochromatic waves whose wavelengths differ by a small amount $d\lambda$ are separated angularly at θ and $\theta + d\theta$. The dispersive power is given by
(A) $d\theta/d\lambda$
(B) $d\theta/\theta$
(C) $d\lambda/\lambda$
(D) $\lambda(d\lambda/d\theta)$

Q.147 A ray of light is incident normally on a prism of refractive index 1.5, as shown. The prism is immersed in a liquid of refractive index 'μ'. The largest value of the angle ACB, so that the ray is totally reflected at the face AC, is 30°. Then the value of μ must be :



(A) $\frac{\sqrt{3}}{2}$
(B) $\frac{5}{3}$
(C) $\frac{4}{3}$
(D) $\frac{3\sqrt{3}}{4}$

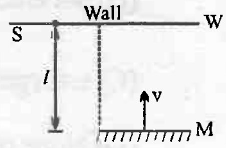
ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 A man of height 170 cm wants to see his complete image in a plane mirror (while standing). His eyes are at a height of 160 cm from the ground.
(A) Minimum length of the mirror = 80 cm
(B) Minimum length of the mirror = 85 cm.
(C) Bottom of the mirror should be at a height 80 cm.
(D) Bottom of the mirror should be at a height 85 cm.

Q.2 Two plane mirrors at an angle such that a ray incident on a mirror undergoes a total deviation of 240° after two reflections.
(A) the angle between the mirror is 60°
(B) the number of images formed by this system will be 5, if an object is placed symmetrically between the mirrors.
(C) the no. of images will be 5 if an object is kept unsymmetrically between the mirrors.
(D) a ray will retrace its path after 2 successive reflections, if the angle of incidence on one mirror is 60°.

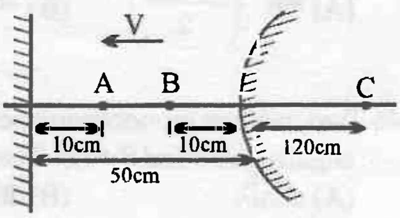
Q.3 A flat mirror M is arranged parallel to a wall W at a distance l from it. The light produced by a point source S kept on the wall is reflected by the mirror and produces a light spot on the wall. The mirror moves with velocity v towards the wall.



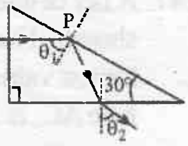
(A) The spot of light will move with the speed v on the wall.
(B) The spot of light will not move on the wall.
(C) As the mirror comes closer the spot of light will become larger and shift away from the wall with speed larger then v.
(D) The size of the light spot on the wall remains the same.

Q.4 A concave mirror cannot form
(A) virtual image of virtual object
(B) virtual image of a real object
(C) real image of a real object
(D) real image of a virtual object.

Q.5 In the figure shown consider the first reflection at the plane mirror and second at the convex mirror. AB is object.
(A) the second image is real, inverted of 1/5 th magnification
(B) the second image is virtual and erect with magnification 1/5
(C) the second image moves towards the convex mirror
(D) the second image moves away from the convex mirror.



Q.6 A ray of light is incident normally on one face of 30° – 60° – 90° prism of refractive index 5/3 immersed in water of refractive index 4/3 as shown in figure.

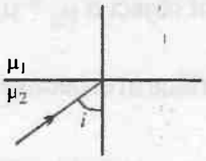


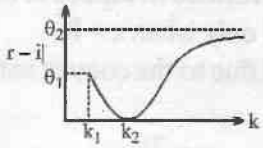
(A) The exit angle θ_2 of the ray is $\sin^{-1}(5/8)$
(B) The exit angle θ_2 of the ray is $\sin^{-1}(5/4\sqrt{3})$
(C) Total internal reflection at point P ceases if the refractive index of water is increased to $5/2\sqrt{3}$ by dissolving some substance.
(D) Total internal reflection at point P ceases if the refractive index of water is increased to 5/6 by dissolving some substance.

Q.7 A ray of light in a liquid of refractive index 1.4, approaches the boundary surface between the liquid and air at an angle of incidence whose sine is 0.8. Which of the following statements is correct about the behaviour of the light

(A) It is impossible to predict the behavior of the light ray on the basis of the information supplied.
(B) The sine of the angle of refraction of the emergent ray will less than 0.8.
(C) The ray will be internally reflected
(D) The sine of the angle of refraction of the emergent ray will be greater than 0.8.

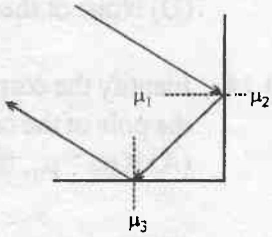
Q.8 The figure shows a ray incident at an angle $i = \pi/3$. If the plot drawn shown the variation of $|r - i|$ versus $\frac{\mu_1}{\mu_2} = k$, (r = angle of refraction)





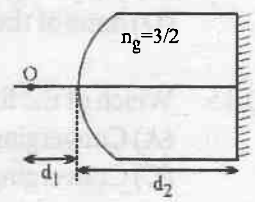
(A) the value of k_1 is $\frac{2}{\sqrt{3}}$
(B) the value of $\theta_1 = \pi/6$
(C) the value of $\theta_2 = \pi/3$
(D) the value of k_2 is 1

Q.9 In the diagram shown, a ray of light is incident on the interface between 1 and 2 at angle slightly greater than critical angle. The light suffers total internal reflection at this interface. After that the light ray falls at the interface of 1 and 3, and again it suffers total internal reflection. Which of the following relations should hold true?



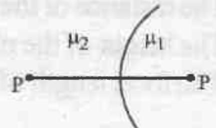
(A) $\mu_1 < \mu_2 < \mu_3$
(B) $\mu_1^2 - \mu_2^2 > \mu_3^2$
(C) $\mu_1^2 - \mu_3^2 > \mu_2^2$
(D) $\mu_1^2 + \mu_2^2 > \mu_3^2$

Q.10 In the figure shown a point object O is placed in air on the principal axis. The radius of curvature of the spherical surface is 60 cm. I_f is the final image formed after all the refractions and reflections.



(A) If d_1 = 120 cm, then the 'I_f' is formed on 'O' for any value of d_2.
(B) If d_1 = 240 cm, then the 'I_f' is formed on 'O' only if d_2 = 360 cm.
(C) If d_1 = 240 cm, then the 'I_f' is formed on 'O' for all values of d_2.
(D) If d_1 = 240 cm, then the 'I_f' cannot be formed on 'O'.

Q.11 Two refracting media are separated by a spherical interface as shown in the figure. PP' is the principal axis, μ_1 and μ_2 are the refractive indices of medium of incidence and medium of refraction respectively. Then:



(A) if $\mu_2 > \mu_1$, then there cannot be a real image of real object.
(B) if $\mu_2 > \mu_1$, then there cannot be a real image of virtual object.
(C) if $\mu_1 > \mu_2$, then there cannot be a virtual image of virtual object.
(D) if $\mu_1 > \mu_2$, then there cannot be a real image of real object.

Question No. 12 to 14(3 questions)

A curved surface of radius R separates two medium of refractive indices μ_1 and μ_2 as shown in figures A and B

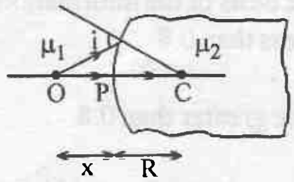


Fig. A

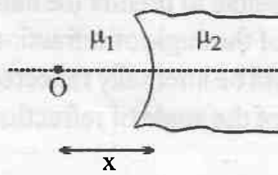


Fig. B

Q.12 Choose the correct statement(s) related to the real image formed by the object O placed at a distance x, as shown in figure A
(A) Real image is always formed irrespective of the position of object if $\mu_2 > \mu_1$
(B) Real image is formed only when $x > R$
(C) Real image is formed due to the convex nature of the interface irrespective of μ_1 and μ_2
(D) None of these

Q.13 Choose the correct statement(s) related to the virtual image formed by object O placed at a distance x, as shown in figure A
(A) Virtual image is formed for any position of O if $\mu_2 < \mu_1$
(B) Virtual image can be formed if $x > R$ and $\mu_2 < \mu_1$
(C) Virtual image is formed if $x < R$ and $\mu_2 > \mu_1$
(D) None of these

Q.14 Identify the correct statement(s) related to the formation of images of a real object O placed at x from the pole of the concave surface, as shown in figure B
(A) If $\mu_2 > \mu_1$, then virtual image is formed for any value of x
(B) If $\mu_2 < \mu_1$, then virtual image is formed if $x < \frac{\mu_1 R}{\mu_1 - \mu_2}$
(C) If $\mu_2 < \mu_1$, then real image is formed for any value of x
(D) none of these

Q.15 Which of the following can form diminished, virtual and erect image of your face.
(A) Converging mirror (B) Diverging mirror
(C) Converging lens (D) Diverging lens

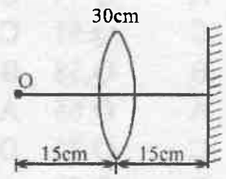
Q.16 A convex lens forms an image of an object on a screen. The height of the image is 9 cm. The lens is now displaced until an image is again obtained on the screen. The height of this image is 4 cm. The distance between the object and the screen is 90cm.
(A) The distance between the two positions of the lens is 30cm.
(B) The distance of the object from the lens in its first position is 36cm.
(C) The height of the object is 6cm.
(D) The focal length of the lens is 21.6 cm.

Q.17 A diminished image of an object is to be obtained on a large screen 1 m from it. This can be achieved by
(A) using a convex mirror of focal length less than 0.25 m
(B) using a concave mirror of focal length less than 0.25 m
(C) using a convex lens of focal length less than 0.25 m
(D) using a concave lens of focal length less than 0.25 m

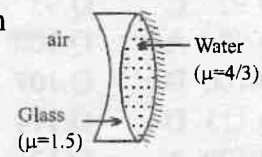
Q.18 Which of the following quantities related to a lens depend on the wavelength of the incident light ?
(A) Refractive index (B) Focal length
(C) Power (D) Radii of curvature

Q.19 A thin lens with focal length f to be used as a magnifying glass. Which of the following statements regarding the situation is true?
(A) A converging lens may be used, and the object be placed at a distance greater than 2f from the lens.
(B) A diverging lens may be used, and the object be placed between f and 2f from the lens.
(C) A converging lens may be used, and the object be placed at a distance less than f from the lens.
(D) A diverging lens may be used, and the object be placed at any point other than the focal point.

Q.20 An object O is kept infront of a converging lens of focal length 30cm behind which there is a plane mirror at 15cm from the lens.
(A) the final image is formed at 60cm from the lens towards right of it
(B) the final image is at 60cm from lens towards left of it.
(C) the final image is real.
(D) the final image is virtual.



Q.21 The radius of curvature of the left and right surface of the concave lens are 10cm and 15cm respectively. The radius of curvature of the mirror is 15cm.
(A) equivalent focal length of the combination is -18cm.
(B) equivalent focal length of the combination is +36cm.
(C) the system behaves like a concave mirror.
(D) the system behaves like a convex mirror.



Q.22 A man wishing to get a picture of a Zebra photographed a white donkey after fitting a glass with black streaks onto the objective of his camera.
(A) the image will look like a white donkey on the photograph.
(B) the image will look like a Zebra on the photograph.
(C) the image will be more intense compared to the case in which no such glass is used.
(D) the image will be less intense compared to the case in which no such glass is used.

Q.23 For refraction through a small angled prism, the angel of deviation :
(A) increases with the increase in R.I. of prism.
(B) will decrease with the increase in R.I. of prism.
(C) is directly proportional to the angle of prism.
(D) will be 2D for a ray of R.I.=2.4 if it is D for a ray of R.I.=1.2

Q.24 For the refraction of light through a prism
(A) For every angle of deviation there are two angles of incidence.
(B) The light travelling inside an equilateral prism is necessarily parallel to the base when prism is set for minimum deviation.
(C) There are two angles of incidence for maximum deviation.(for A < 20°C)
(D) Angle of minimum deviation will increase if refractive index of prism is increased keeping the outside medium unchanged if $\mu_P > \mu_S$.

Answer Key

ONLY ONE OPTION IS CORRECT

Q.1 D	Q.2 D	Q.3 C	Q.4 A	Q.5 C	Q.6 A	Q.7 B
Q.8 C	Q.9 A	Q.10 D	Q.11 C	Q.12 A	Q.13 C	Q.14 B
Q.15 C	Q.16 B	Q.17 C	Q.18 A	Q.19 B	Q.20 C	Q.21 B
Q.22 A	Q.23 A	Q.24 A	Q.25 B	Q.26 D	Q.27 A	Q.28 C
Q.29 D	Q.30 D	Q.31 C	Q.32 A	Q.33 D	Q.34 A	Q.35 D
Q.36 A	Q.37 D	Q.38 C	Q.39 A	Q.40 D	Q.41 A	Q.42 C
Q.43 A	Q.44 C	Q.45 B	Q.46 A	Q.47 C	Q.48 D	Q.49 A
Q.50 C	Q.51 C	Q.52 D	Q.53 A	Q.54 A	Q.55 A	Q.56 B
Q.57 B	Q.58 B	Q.59 B	Q.60 A	Q.61 B	Q.62 C	Q.63 B
Q.64 A	Q.65 A	Q.66 C	Q.67 B	Q.68 C	Q.69 B	Q.70 C
Q.71 C	Q.72 D	Q.73 A	Q.74 C	Q.75 C	Q.76 C	Q.77 C
Q.78 C	Q.79 A	Q.80 A	Q.81 D	Q.82 A	Q.83 D	Q.84 D
Q.85 D	Q.86 C	Q.87 B	Q.88 B	Q.89 D	Q.90 C	Q.91 A
Q.92 C	Q.93 A	Q.94 C	Q.95 A	Q.96 B	Q.97 B	Q.98 C
Q.99 A	Q.100 B	Q.101 B	Q.102 C	Q.103 B	Q.104 D	Q.105 C
Q.106 D	Q.107 B	Q.108 D	Q.109 A	Q.110 D	Q.111 D	Q.112 B
Q.113 D	Q.114 A	Q.115 D	Q.116 C	Q.117 D	Q.118 A	Q.119 B
Q.120 A	Q.121 C	Q.122 B	Q.123 B	Q.124 B	Q.125 C	Q.126 B
Q.127 A	Q.128 D	Q.129 A	Q.130 B	Q.131 A	Q.132 C	Q.133 C
Q.134 A	Q.135 A	Q.136 B	Q.137 D	Q.138 D	Q.139 C	Q.140 A
Q.141 B	Q.142 B	Q.143 A	Q.144 D	Q.145 A	Q.146 B	Q.147 D

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1 B,C	Q.2 A,B,C,D	Q.3 B,D	Q.4 A
Q.5 B,C	Q.6 A,C	Q.7 C	Q.8 B,C,D
Q.9 B,C,D	Q.10 A,B	Q.11 A,C	Q.12 D
Q.13 A,B	Q.14 A,B	Q.15 B,D	Q.16 B,C,D
Q.17 C	Q.18 A,B,C	Q.19 C	Q.20 B,C
Q.21 A,C	Q.22 A,D	Q.23 A,C	Q.24 B,C,D

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

GEOMETRICAL OPTICS

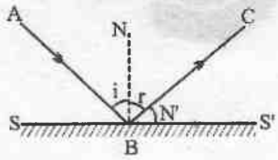
CONTENTS

KEY CONCEPTS

1. LAWS OF REFLECTION :

(i) The incident ray (AB), the reflected ray (BC) and normal (NN') to the surface (SC') of reflection at the point of incidence (B) lie in the same plane. This plane is called the plane of incidence (also plane of reflection).

(ii) The angle of incidence (the angle between normal and the incident ray) and the angle of reflection (the angle between the reflected ray and the normal) are equal $\boxed{\angle i = \angle r}$



2. OBJECT :

(a) **Real :** Point from which rays actually diverge.

(b) **Virtual :** Point towards which rays appear to converge

3. IMAGE :

Image is decided by reflected or refracted rays only. The point image for a mirror is that point

(i) Towards which the rays reflected from the mirror, actually converge (real image).

OR

(ii) From which the reflected rays appear to diverge (virtual image).

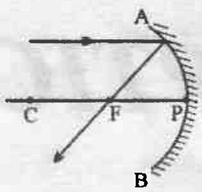
4. CHARACTERISTICS OF REFLECTION BY A PLANE MIRROR :

(a) The size of the image is the same as that of the object.

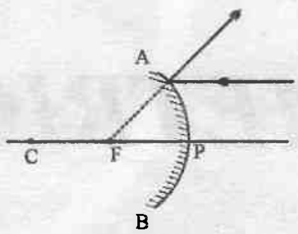
(b) For a real object the image is virtual and for a virtual object the image is real.

(c) For a fixed incident light ray, if the mirror be rotated through an angle θ the reflected ray turns through an angle 2θ.

5. SPHERICAL MIRRORS :



Concave



Convex

6. PARAXIAL RAYS : Rays which forms very small angle with axis are called paraxial rays.

7. SIGN CONVENTION :

We follow cartesian co-ordinate system convention according to which

(a) The pole of the mirror is the origin.

(b) The direction of the incident rays is considered as positive x-axis.

(c) Vertically up is positive y-axis.

Note : According to above convention radius of curvature and focus of concave mirror is negative and of convex mirror is positive.

8. MIRROR FORMULA : $\boxed{\frac{1}{f} = \frac{1}{v} + \frac{1}{u}}$.

f = x-coordinate of focus ; u = x-coordinate of object ;
v = x-coordinate of image

Note : Valid only for paraxial rays.

9. **TRANSVERSE MAGNIFICATION :** $m = \frac{h_2}{h_1} = -\frac{v}{u}$

h_2 = y co-ordinate of images h_1 = y co-ordinate of the object
(both perpendicular to the principle axis of mirror)

10. **NEWTON'S FORMULA :**
Applicable to a pair of real object and real image position only. They are called conjugate positions or foci. X, Y are the distance along the principal axis of the real object and real image respectively from the principal focus.

$$XY = f^2$$

11. **OPTICAL POWER :** Optical power of a mirror (in Diopters) $= -\frac{1}{f}$;
f = focal length (in meters) with sign.

REFRACTION - PLANE SURFACE

1. **LAWS OF REFRACTION (AT ANY REFRACTING SURFACE) :**

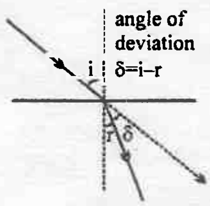
(i) The incident ray (AB), the normal (NN') to the refracting surface (II') at the point of incidence (B) and the refracted ray (BC) all lie in the same plane called the plane of incidence or plane of refraction.

(ii) $\frac{\text{Sin i}}{\text{Sin r}} = \text{Constant}$:
for any two given media and for light of a given wave length. This is known as SNELL's Law.

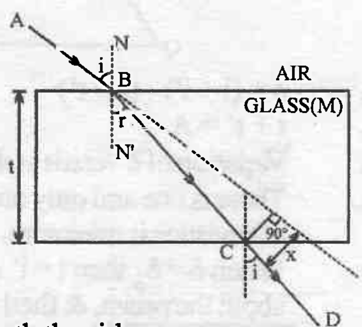
$$\frac{\text{Sin i}}{\text{Sin r}} = {}_1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Note : Frequency of light does not change during refraction.

2. **DEVIATION OF A RAY DUE TO REFRACTION :**



3. **REFRACTION THROUGH A PARALLEL SLAB :**



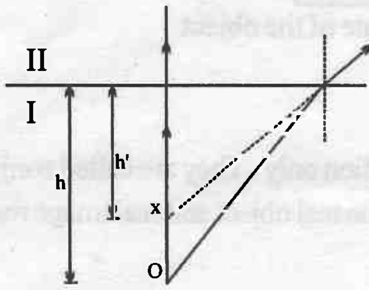
(i) Emerged ray is parallel to the incident ray, if medium is same on both sides.

(ii) Lateral shift $x = \frac{t \sin(i - r)}{\cos r}$

t = thickness of slab

Note : Emerged ray will not be parallel to the incident ray if the medium on both the sides are different.

4. APPARENT DEPTH OF SUBMERGED OBJECT :

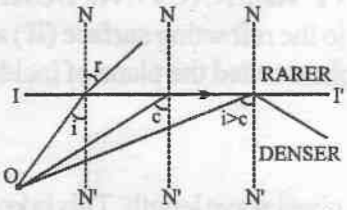


(h' < h)

at near normal incidence $h' = \dfrac{\mu_2}{\mu_1} h$

Note : h and h' are always measured from surface.

5. CRITICAL ANGLE & TOTAL INTERNAL REFLECTION (T. I. R.)



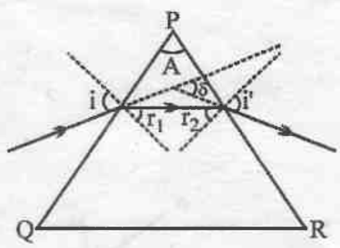
CONDITIONS OF T. I. R.

(i) Ray going from denser to rarer medium

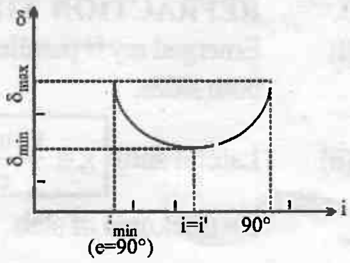
(ii) Angle of incidence should be greater than the critical angle (i > c) .

Critical angle $C = \sin^{-1}\dfrac{n_r}{n_i}$

6. REFRACTION THROUGH PRISM :



1. $\delta = (i + i') - (r + r')$
2. $r + r' = A$
3. Variation of δ versus i (shown in diagram) .
4. There is one and only one angle of incidence for which the angle of deviation is minimum.



When $\delta = \delta_m$ then $i = i'$ & $r = r'$, the ray passes symetrically about the prism, & then

$$n = \frac{\sin\left[\frac{A+\delta m}{2}\right]}{\sin\left[\frac{A}{2}\right]}$$, where n = absolute R.I. of glass .

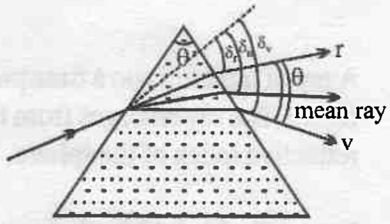
Note : When the prism is dipped in a medium then n = R.I. of glass w.r.t. medium .

5. For a thin prism ($A \le 10^\circ$) ; $\delta = (n-1)A$

6. **DISPERSION OF LIGHT :**

The angular spilitting of a ray of white light into a number of components when it is refracted in a medium other than air is called ***Dispersion of Light.***

7. **Angle of Dispersion :** Angle between the rays of the extreme colours in the refracted (dispersed) light is called ***Angle of Dispersion .*** $\theta = \delta_v - \delta_r$.



8. Dispersive power (ω) of the medium of the material of prism .

$$\omega = \frac{\text{angular dispersion}}{\text{deviation of mean ray (yellow)}}$$

For small angled prism ($A < 10^\circ$)

$$\omega = \frac{\delta_v - \delta_R}{\delta y} = \frac{n_v - n_R}{n-1} \quad ; n = \frac{n_v + n_R}{2}$$

n_v, n_R & n are R. I. of material for violet, red & yellow colours respectively .

9. **COMBINATION OF TWO PRISMS :**

(i) **ACHROMATIC COMBINATION :** It is used for deviation without dispersion .

Condition for this $(n_v - n_r) A = (n'_v - n'_r) A'$.

$$\text{Net mean deviation} = \left[\frac{n_v + n_R}{2} - 1\right] A - \left[\frac{n'_v + n'_R}{2} - 1\right] A' .$$

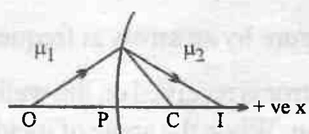
or $\omega\delta + \omega'\delta' = 0$ where ω, ω′ are dispersive powers for the two prisms & δ, δ′ are the mean deviation.

(ii) **DIRECT VISION COMBINATION :** It is used for producing disperion without deviation condition for this $\left[\frac{n_v + n_R}{2} - 1\right] A = \left[\frac{n'_v + n'_R}{2} - 1\right] A'$.

Net angle of dispersion = $(n_v - n_r) A = (n_v' - n_r') A'$.

REFRACTION AT SPERICAL SURFACE

1.(a) $$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$



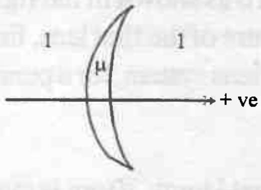
v, u & R are to be kept with sign

as v = PI
u = –PO
R = PC

(Note radius is with sign)

(b) $$m = \frac{\mu_1 v}{\mu_2 u}$$

2. **LENS FORMULA :**



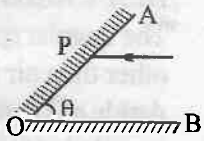
(a) $$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

(b) $$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

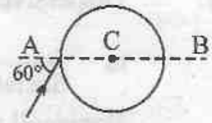
(c) $$m = \frac{v}{u}$$

EXERCISE # I

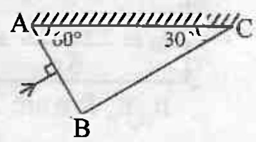
Q.1 Two plane mirrors are inclined at angle θ as shown in figure. If a ray parallel to OB strikes the other mirror at P and finally emerges parallel to OA after two reflection then find θ.



Q.2 A ray of light falls on a transparent sphere with centre at C as shown in figure. The ray emerges from the sphere parallel to line AB. Find the refractive index of the sphere.



Q.3 Face AC of a right angled prism ($\mu_\gamma = 1.5$) coated with a thin film of liquid as shown in figure. Light is allowed to fall normally on the face AB of the prism. In order that the ray of light gets totally reflected, what can be the maximum refractive index of liquid?

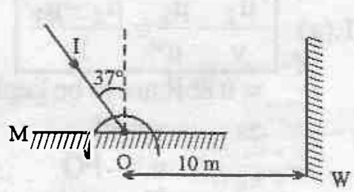


Q.4 A tiny air bubble inside a glass slab appears to be 6 cm deep when viewed form one side and 4 cm deep when viewed from the other side. Assuming $\mu_{glass} = 3/2$. Find the thickness of slab.

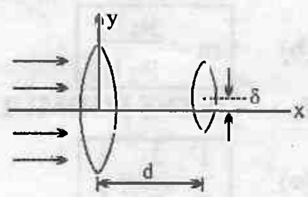
Q.5 A prism of refractive index $\sqrt{2}$ has a refracting angle of 30°. One of the refracting surfaces of the prism is polished. For the beam of monochromatic light to retrace its path, find the angle of incidence on the refracting surface.

Q.6 A plano-convex lens, when silvered on the plane side, behaves like a concave mirror of focal length 30 cm. When it is silvered on the convex side, it behaves like a concave mirror of focal length 10 cm. Find the refractive index of the material of the lens.

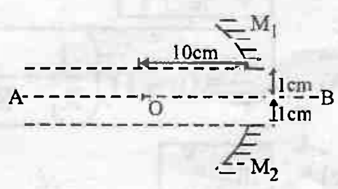
Q.7 A light ray I is incident on a plane mirror M. The mirror is rotated in the direction as shown in the figure by an arrow at frequency $\frac{9}{\pi}$ rev/sec. The light reflected by the mirror is received on the wall W at a distance 10 m from the axis of rotation. When the angle of incidence becomes 37° find the speed of the spot (a point) on the wall?



Q.8 Two thin convex lenses of focal lengths f_1 and f_2 are separated by a horizontal distance d where ($d < f_1$, $d < f_2$) & their centres are displaced by a vertical separation δ as shown in the figure. Taking the origin of coordinates O, at the centre of the first lens, find the x & y coordinates of the focal point of this lens system, for a parallel beam of rays coming from the left.



Q.9 A concave mirror of focal length 20 cm is cut into two parts from the middle and the two parts are moved perpendicularly by a distance 1 cm from the previous principal axis AB. Find the distance between the images formed by the two parts?



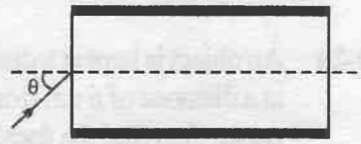
Q.10 A balloon is rising up along the axis of a concave mirror of radius of curvature 20 m. A ball is dropped from the balloon at a height 15 m from the mirror when the balloon has velocity 20 m/s. Find the speed of the image of the ball formed by concave mirror after 4 seconds? [Take : $g = 10\ m/s^2$]

Q.11 An object is kept on the principal axis of a convex mirror of focal length 10 cm at a distance of 10 cm from the pole. The object starts moving at a velocity 20 mm/sec towards the mirror at angle 30° with the principal axis. What will be the speed of its image and direction with the principal axis at that instant?

Q.12 A thin rod of length d/3 is placed along the principal axis of a concave mirror of focal length = d such that its image, which is real and elongated, just touches the rod. Find the length of the image?

Q.13 A point object is placed 33 cm from a convex mirror of curvature radius = 40 cm. A glass plate of thickness 6 cm and index 2.0 is placed between the object and mirror, close to the mirror. Find the distance of final image from the object?

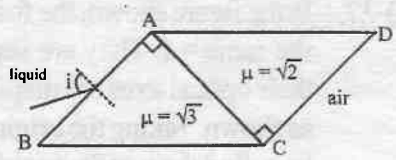
Q.14 A long solid cylindrical glass rod of refractive index 3/2 is immersed in a liquid of refractive index $\frac{3\sqrt{3}}{4}$. The ends of the rod are perpendicular to the central axis of the rod. a light enters one end of the rod at the central axis as shown in the figure. Find the maximum value of angle θ for which internal reflection occurs inside the rod?



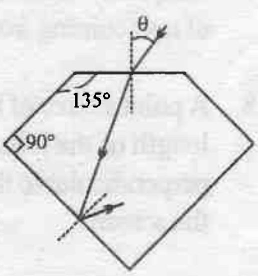
Q.15 A ray of light moving along the unit vector $(-\mathbf{i}-2\,\mathbf{j})$ undergoes refraction at an interface of two media, which is the x-z plane. The refractive index for $y > 0$ is 2 while for $y < 0$, it is $\sqrt{5}/2$. Find the unit vector along which the refracted ray moves?

Q.16 A slab of glass of thickness 6 cm and index 1.5 is place somewhere in between a concave mirror and a point object, perpendicular to the mirror's optical axis. The radius of curvature of the mirror is 40 cm. If the reflected final image coincides with the object, then find the distance of the object from the mirror?

Q.17 A ray of light from a liquid ($\mu = \sqrt{3}$) is incident on a system of two right-angled prisms of refractive indiccs $\sqrt{3}$ and $\sqrt{2}$ as shown in the figure. The ray of light suffers zero net deviation when it emerges into air from the surface CD. Find the angle of incidence?

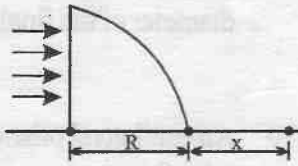


Q.18 A ray of light enters a diamond (n = 2) from air and is being internally reflected near the bottom as shown in the figure. Find maximum value of angle θ possible?

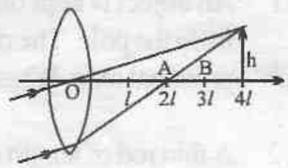


Q.19 A parallel beam of light is incident on a transparent sphere of refractive index 'n'. If the beam finally gets focussed at a point situated at a distance = 2 × (radius of sphere) from the centre of the sphere, then find n?

Q.20 A uniform, horizontal beam of light is incident upon a quarter cylinder of radius R = 5 cm, and has a refractive index $2/\sqrt{3}$. A patch on the table for a distance 'x' from the cylinder is unilluminated. find the value of 'x'?



Q.21 A thin converging lens L_1 forms a real image of an object located far away from the lens as shown in the figure. The image is located at a distance $4l$ and has height h. A diverging lens of focal length l is placed $2l$ from lens L_1 at A. Another converging lens of focal length $2l$ is placed $3l$ from lens L_1 at B. Find the height of final image thus formed?



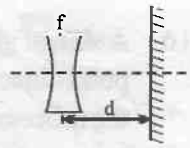
Q.22 An object is placed at a certain distance from a screen. A convex lens of focal length 40 cm is placed between the screen and the object. A real image is formed on the screen for two positions of the lens, which differ by a distance of $10\sqrt{17}$ cm. Find the distance of the object from the screen?

Q.23 A point object is placed at a distance of 25 cm from a convex lens of focal length 20 cm. If a glass slab of thickness t and refractive index 1.5 is inserted between the lens and object. The image is formed at infinity. Find the thickness t ?

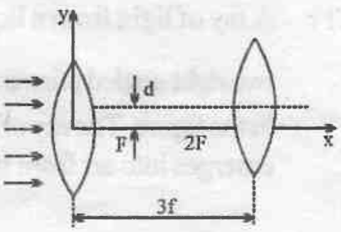
Q.24 An object is kept at a distance of 16 cm from a thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens the image formed is virtual. If the size of the image formed are equal, then find the focal length of the lens?

Q.25 A thin convex lens forms a real image of a certain object 'p' times its size. The size of real image becomes 'q' times that of object when the lens is moved nearer to the object by a distance 'a' find focal length of the lens ?

Q.26 A diverging lens of focal length 10 cm is placed 10 cm in front of a plane mirror as shown in the figure. Light from a very far away source falls on the lens. Find the image of source due to plane mirror (before hitting lens again) at a distance from mirror?

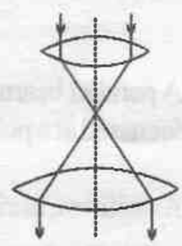


Q.27 In the figure shown, the focal length of the two thin convex lenses is the same = f. They are separated by a horizontal distance 3f and their optical axes are displaced by a vertical separation 'd' ($d << f$), as shown. Taking the origin of coordinates O at the centre of the first lens, find the x and y coordinates of the point where a parallel beam of rays coming from the left finally get focussed?



Q.28 A point source of light is kept at a distance of 15 cm from a converging lens, on its optical axis. The focal length of the lens is 10 cm and its diameter is 3 cm. A screen is placed on the other side of the lens, perpendicular to the axis of lens, at a distance 20 cm from it. Then find the area of the illuminated part of the screen?

Q.29 Consider a 'beam expander' which consists of two converging lenses of focal lengths 40 cm and 100 cm having a common optical axis. A laser beam of diameter 4 mm is incident on the 40 cm focal length lens. The diameter of the final beam will be (see figure)



Q.30 An equilateral prism deviates a ray through 23° for two angles of incidence differing by 23°. Find μ of the prism?

List of recommended questions from I.E. Irodov.
5.13 to 17, 5.21 to 24, 5.26, 5.27, 5.31, 5.34 to 37

EXERCISE # II

Q.1 An observer whose least distance of distinct vision is 'd', views his own face in a convex mirror of radius of curvature 'r'. Prove that magnification produced can not exceed $\frac{r}{d+\sqrt{d^2+r^2}}$.

Q.2 Two identical convex lenses L_1 and L_2 are placed at a distance of 20 cm from each other on the common principal axis. The focal length of each lens is 15 cm and the lens L_2 is to the right of lens A. A point object is placed at a distance of 20 cm on the left of lens L_1, on the common axis of two lenses. Find, where a convex mirror of radius of curvature 5 cm should be placed so that the final image coincides with the object?

Q.3 A thin converging lens is arranged between a small illuminated object & a screen so that an image of the object of linear magnification 3 is formed on a screen. The object and the screen are then 64 cm apart. A thin biconcave lens is then placed between the converging lens & the screen so that the lenses are coaxial & 6 cm apart. To restore a sharply focussed image on the image screen the object was moved away from the converging lens through a distance of 14 cm. The biconcave lens has a surface of radii of curvature 14 cm & 21 cm. Calculate the focal length of the biconcave lens. Also find the R. I. of the biconcave lens.

Q.4 A surveyor on one bank of canal observed the image of the 4 inch and 17 ft marks on a vertical staff, which is partially immersed in the water and held against the bank directly opposite to him, coincides. If the 17ft mark and the surveyor's eye are both 6ft above the water level, estimate the width of the canal, assuming that the refractive index of the water is 4/3.

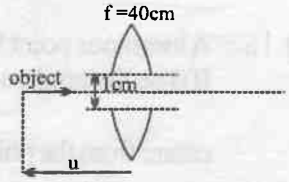
Q.5 Two thin similar watch glass pieces are joined together, front to front, with rear portion silvered and the combination of glass pieces is placed at a distance $a = 60$ cm from a screen. A small object is placed normal to the optical axis of the combination such that its two times magnified image is formed on the screen. If air between the glass pieces is replaced by water ($\mu = 4/3$), calculate the distance through which the object must be displaced so that a sharp image is again formed on the screen.

Q.6 A concave mirror has the form of a hemisphere with a radius of R = 60 cm. A thin layer of an unknown transparent liquid is poured into the mirror. The mirror-liquid system forms one real image and another real image is formed by mirror alone, with the source in a certain position. One of them coincides with the source and the other is at a distance of $l = 30$ cm from source. Find the possible value(s) refractive index μ of the liquid.

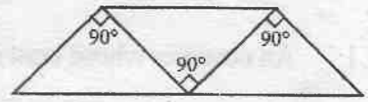
Q.7 A ray of light refracted through a sphere, whose material has refractive index μ in such a way that it passes through the extremities of two radii which make an angle θ with each other. Prove that if α is the deviation of the ray caused by its passage through the sphere

$$\cos\frac{1}{2}(0-\alpha) = \mu\cos\frac{\theta}{2}$$

Q.8 In the figure shown, find the relative speed of approach/separation of the two final images formed after the light rays pass through the lens, at the moment when u = 30 cm. The speed object = 4 cm/s. The two lens halves are placed symmetrically w.r.t. the moving object.

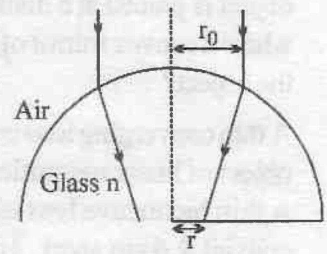


Q.9 Three right angled prisms of refractive indices μ_1, μ_2 and μ_3 are joined together so that the faces of the middle prism in are in contact each with one of the outside prisms. If the ray passes through the composite block undeviated, show that $\mu_1^2 + \mu_3^2 - \mu_2^2 = 1$.

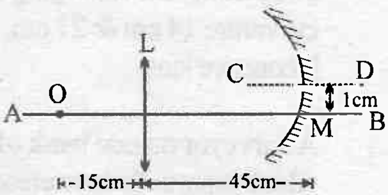


Q.10 Two rays are incident on a spherical mirror of radius of R = 5 cm parallel to its optical axis at the distance $h_1 = 0.5$ cm and $h_2 = 3$ cm. Determine the distance Δx between the points at which these rays intersect the optical axis after being reflected at the mirror.

Q.11 A beam of light is incident vertically on a glass hemisphere of radius R lying with its plane side on a table. The axis of the beam coincides with the vertical axis passing through the centre of the base of the hemisphere and the radius r_0 of the cross section of the beam is smaller than R. Find the radius of the luminous spot formed on the table.



Q.12 In the figure shown L is a converging lens of focal length 10cm and M is a concave mirror of radius of curvature 20cm. A point object O is placed in front of the lens at a distance 15cm. AB and CD are optical axes of the lens and mirror respectively. Find the distance of the final image formed by this system from the optical centre of the lens. The distance between CD & AB is 1 cm.



Q.13 A thief is running away in a car with velocity of 20 m/s. A police jeep is following him, which is sighted by thief in his rear view mirror which is a convex mirror of focal length 10 m. He observes that the image of jeep is moving towards him with a velocity of 1 cm/s. If the magnification of the mirror for the jeep at that time is 1/10. Find

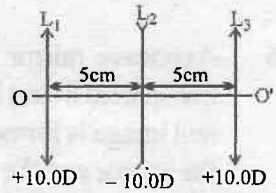
(a) actual speed of jeep

(b) rate at which magnification is changing.

Assume that police jeep is on axis of the mirror.

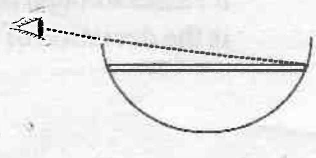
Q.14 The figure illustrates an aligned system consisting of three thin lenses. The system is located in air. Determine:

(a) the position (relative to right most lens) of the point of convergence of a parallel ray incoming from the left after passing through the system;



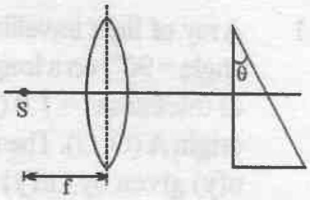
(b) The distance between the first lens and a point lying on the axis to the left of the system, at which that point and its image are located symmetrically with respect to the lens system?

Q.15 A circular disc of diameter d lies horizontally inside a metallic hemispherical bowl radius a. The disc is just visible to an eye looking over the edge. The bowl is now filled with a liquid of refractive index μ. Now, the whole of the disc is just visible to the eye in the same position. Show that $d = 2a\dfrac{(\mu^2 - 1)}{(\mu^2 + 1)}$.



Q.16 A luminous point P is inside a circle. A ray enters from P and after two reflections by the circle, return to P. If θ be the angle of incidence, a the distance of P from the centre of the circle and b the distance of the centre from the point where the ray in its course crosses the diameter through P, prove that $\tan\theta = \sqrt{\dfrac{a-b}{a+b}}$.

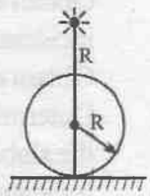
Q.17 A glass wedge with a small angle of refraction θ is placed at a certain distance from a convergent lens with a focal length f, one surface of the wedge being perpendicular to the optical axis of the lens. A point sources S of light is on the other side of the lens at its focus. The rays reflected from the wedge (not from base) produce, after refraction in the lens, two images of the source displaced with respect to each other by d. Find the refractive index of the wedge glass.



Q.18 An opaque sphere of radius R lies on a horizontal plane. On the perpendicular through the point of contact there is a point source of light a distance R above the sphere.

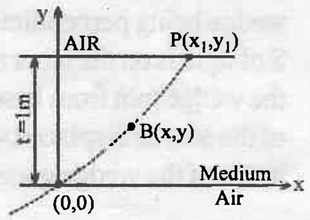
(a) Show that the area of the shadow on the plane is $3\pi R^2$.

(b) A transparent liquid of refractive index $\sqrt{3}$ is filled above the plane such that the sphere is just covered with the liquid. Show that the area of shadow now becomes $2\pi R^2$.



EXERCISE # III

Q.1 A ray of light travelling in air is incident at grazing angle (incident angle = 90°) on a long rectangular slab of a transparent medium of thickness t = 1.0 (see figure). The point of incidence is the origin A (O, O). The medium has a variable index of refraction n(y) given by : $n(y) = [ky^{3/2} + 1]^{1/2}$, where $k = 1.0\ m^{-3/2}$. The refractive index of air is 1.0 .



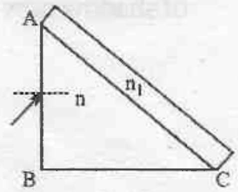
(i) Obtain a relation between the slope of the trajectory of the ray at a point B (x , y) in the medium and the incident angle at that point.

(ii) Obtain an equation for the trajectory y (x) of the ray in the medium.

(iii) Determine the coordinates (x_1, y_1) of the point P, where the ray the ray intersects the upper surface of the slab-air boundary .

(iv) Indicate the path of the ray subsequently . [JEE '95]

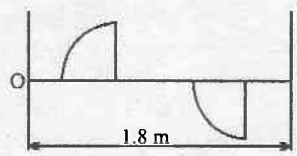
Q.2 A right angle prism (45° – 90° – 45°) of refractive index n has a plate of refractive index n_1 ($n_1 < n$) cemented to its diagonal face. The assembly is in air. a ray is incident on AB (see the figure) .



(i) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

(ii) Assuming n = 1.352 . Calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated . [JEE '96]

Q.3 A thin plano–convex. Lens of focal length F is split into two halves, one of the halves is shifted along the optical axis. The separation between object and image planes is 1.8 m. The magnification of the image formed by one of the half lenses is 2. Find the focal length of the lens and separation between the two halves. Draw the ray diagram for image formation. [JEE '96]

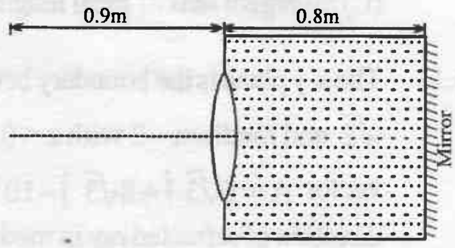


Q.4 Which of the following form(s) a virtual & erect image for all positions of the real object ?
(A) Convex lens (B) Concave lens (C) Convex mirror (D) Concave mirror
[JEE '96]

Q.5 A small fish, 0.4 m below the surface of a lake, is viewed through a simple converging lens of focal length 3 m . The lens is kept at 0.2m above the water surface such that the fish lies on the optical axis of the lens. Find the image of the fish seen by the observer . The refractive index of the water is 4/3.
[REE '96]

Q.6(i) An eye specialist prescribes spectacles having a combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm . The power of this lens combination in diopters is :
(A) + 1.5 (B) – 1.5 (C) + 6.67 (D) – 6.67
[JEE '97]

(ii) A thin equiconvex lens of glass of refractive index $\mu = 3/2$ & of focal length 0.3 m in air is sealed into an opening at one end of a tank filled with water ($\mu = 4/3$). On the opposite side of the lens, a mirror is placed inside the tank on the tank wall perpendicular to the lens axis, as shown in figure. The separation between the lens and the mirror is 0.8 m. A small object is placed outside the tank in front of the lens at a distance of 0.9 m from the lens along its axis. Find the position (relative to the lens) of the image of the object formed by the system. [JEE '97]



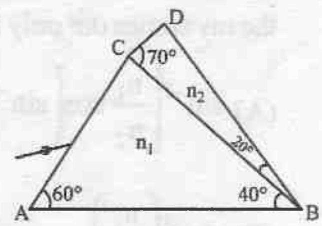
Q.7 Select the correct alternative(s) : [JEE '98]

(i) A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror & C its centre of curvature. A point object is placed at C. It has a real image, also located at C. If the mirror is now filled with water, the image will be:
(A) real, & will remain at C
(B) real, & located at a point between C & ∞
(C) virtual, & located at a point between C & O
(D) real, & located at a point between C & O.

(ii) A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence of 45°. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible value(s) of n from the following :
(A) 1.3 (B) 1.4 (C) 1.5 (D) 1.6

(iii) A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object P placed in air is found to have a real image Q in the glass. The line PQ cuts the surface at a point O and PO = OQ. The distance PO is equal to :
(A) 5R (B) 3R (C) 2R (D) 1.5R

Q.8 A prism of refractive index n_1 & another prism of refractive index n_2 are stuck together without a gap as shown in the figure. The angles of the prisms are as shown. n_1 & n_2 depend on λ, the wavelength of light according to $n_1 = 1.20 + \frac{10.8\times10^4}{\lambda^2}$ & $n_2 = 1.45 + \frac{1.80\times10^4}{\lambda^2}$

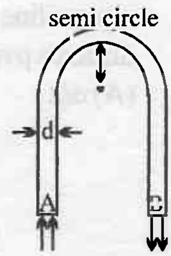


where λ is in nm.

(i) Calculate the wavelength λ_0 for which rays incident at any angle on the interface BC pass through without bending at that interface.

(ii) For light of wavelength λ_0, find the angle of incidence i on the face AC such that the deviation produced by the combination of prisms is minimum. [JEE '98]

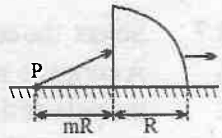
Q.9 A rod made of glass ($\mu = 1.5$) and of square cross-section is bent into the shape shown in figure. A parallel beam of light falls perpendicularly on the plane flat surface A. Referring to the diagram, d is the width of a side & R is the radius of inner semicircle. Find the maximum value of ratio $\frac{d}{R}$ so that all light entering the glass through surface A emerge from the glass through surface B. [REE '98]



Q.10 A concave lens of glass, refractive index 1.5, has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a [JEE '99]
(A) convergent lens of focal length 3.5R (B) convergent lens of focal length 3.0 R.
(C) divergent lens of focal length 3.5 R (D) divergent lens of focal length 3.0 R

Q.11 The x-y plane is the boundary between two transparent media. Medium-1 with $z > 0$ has refractive index $\sqrt{2}$ and medium – 2 with $z < 0$ has a refractive index $\sqrt{3}$. A ray of light in medium –1 given by the vector $A = 6\sqrt{3}\ \hat{i} + 8\sqrt{3}\ \hat{j} - 10\hat{k}$ is incident on the plane of separation. Find the unit vector in the direction of refracted ray in medium -2. [JEE '99]

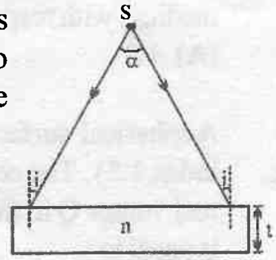
Q.12 A quarter cylinder of radius R and refractive index 1.5 is placed on a table. A point object P is kept at a distance of mR from it. Find the value of m for which a ray from P will emerge parallel to the table as shown in the figure. [JEE '99]



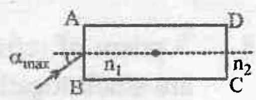
Q.13 Two symmetric double-convex lenses L_1 and L_2 with their radii of curvature 0.2m each are made from glasses with refractive index 1.2 and 1.6 respectively. The lenses with a separation of 0.345 m are submerged in a transparent liquid medium with a refractive index of 1.4. Find the focal lengths of lens L_1 and L_2. An object is placed at a distance of 1.3m from L_1, find the location of its image while the whole system remains inside the liquid. [REE '99]

Q.14 Select the correct alternative. [JEE '2000 (Scr)]

(a) A diverging beam of light from a point source S having divergence angle α, falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is t and the refractive index n, then the divergence angle of the emergent beam is
(A) zero (B) α
(C) $\sin^{-1}(1/n)$ (D) $2\sin^{-1}(1/n)$



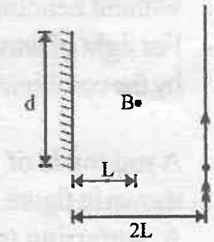
(b) A rectangular glass slab ABCD, of refractive index n_1, is immersed in water of refractive index $n_2 (n_1 > n_2)$. A ray of light is incident at the surface AB of the slab as shown. The maximum value of the angle of incidence α_{max}, such that the ray comes out only from the other surface CD is given by



(A) $\sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\frac{n_2}{n_1}\right)\right]$ (B) $\sin^{-1}\left[n_1\cos\left(\sin^{-1}\frac{1}{n_2}\right)\right]$

(C) $\sin^{-1}\left(\frac{n_1}{n_2}\right)$ (D) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$

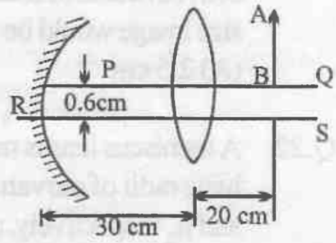
(c) A point source of light B is placed at a distance L in front of the centre of a mirror of width d hung vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance 2L from it as shown. The greatest distance over which he can see the image of the light source in the mirror is
(A) d/2 (B) d (C) 2d (D) 3d



(d) A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refractive indices n_1 and n, respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with

(A) air and placed in air. (B) air and immersed in L_1.
(C) L_1 and immersed in L_2. (D) L_2 and immersed in L_1.

Q.15 A convex lens of focal length 15 cm and a concave mirror of focal length 30 cm are kept with their optic axes PQ and RS parallel but separated in vertical direction by 0.6 cm as shown. The distance between the lens and mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens. If A′B′ is the image after refraction from the lens and reflection from the mirror, find the distance A′B′ from the pole of the mirror and obtain its magnification. Also locate positions of A′ and B′ with respect to the optic axis RS. [JEE 2000]

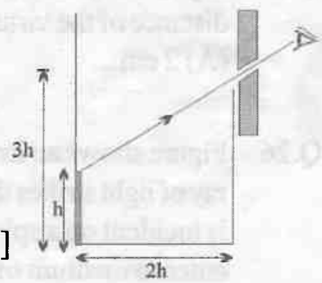


Q.16 A thin equi biconvex lens of refractive index 3/2 is placed on a horizontal plane mirror as shown in the figure. The space between the lens and the mirror is then filled with water of refractive index 4/3. It is found that when a point object is placed 15cm above the lens on its principal axis, the object coincides with its own image. On repeating with another liquid, the object and the image again coincide at a distance 25cm from the lens. Calculate the refractive index of the liquid. [JEE 2001]



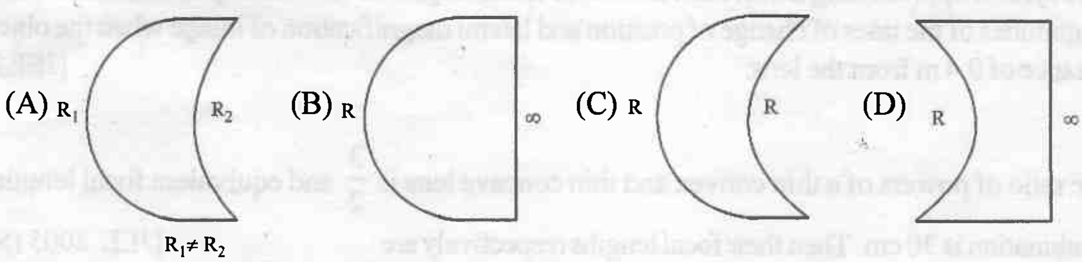
Q.17 The refractive indices of the crown glass for blue and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. An isosceles prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other flint glass isosceles prism is combined with the crown glass prism such that there is no deviation of the incident light. Determine the angle of the flint glass prism. Calculate the net dispersion of the combined system. [JEE 2001]

Q.18 An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is

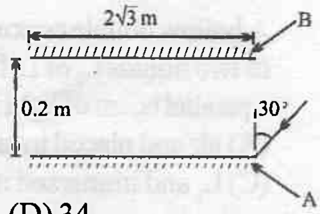


(A) 5/2 (B) $\sqrt{5/2}$
(C) $\sqrt{3/2}$ (D) 3/2 [JEE 2002 (Scr)]

Q.19 Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams. [JEE 2002 (Scr)]



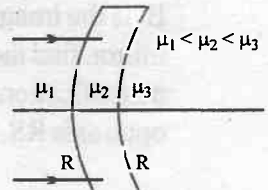
Q.20 Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle of 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is [JEE 2002 (Scr)]



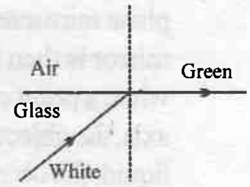
(A) 28 (B) 30 (C) 32 (D) 34

Q.21 A convex lens of focal length 30 cm forms an image of height 2 cm for an object situated at infinity. If a convcave lens of focal length 20 cm is placed coaxially at a distance of 26 cm in front of convex lens then size image would be [JEE 2003 (Scr)]
(A) 2.5 cm (B) 5.0 (C) 1.25 (D) None

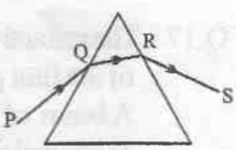
Q.22 A meniscus lens is made of a material of refractive index μ_2. Both its surfaces have radii of curvature R. It has two different media of refractive indices μ_1 and μ_3 respectively, on its two sides (see figure). Calculate its focal length for $\mu_1 < \mu_2 < \mu_3$, when light is incident on it as shown. [JEE 2003]



Q.23 White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains
(A) yellow, orange, red (B) violet, indigo, blue
(C) all colours (D) all coloure except green
[JEE 2004 (Scr)]

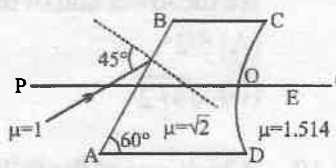


Q.24 A ray of light is incident on an equilateral glass prism placed on a horizontal table. For minimum deviation which of the following is true ? [JEE 2004 (Scr)]
(A) PQ is horizontal (B) QR is horizontal
(C) RS is horizontal (D) Either PQ or RS is horizontal.



Q.25 A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of the sphere is [JEE 2004 (Scr)]
(A) 2 cm (B) 4 cm (C) 6 cm (D) 12 cm

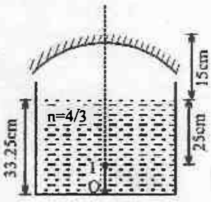
Q.26 Figure shows an irregular block of material of refractive index $\sqrt{2}$. A ray of light strikes the face AB as shown in the figure. After refraction it is incident on a spherical surface CD of radius of curvature 0.4 m and enters a medium of refractive index 1.514 to meet PQ at E. Find the distance OE upto two places of decimal. [JEE 2004]



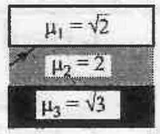
Q.27 An object is approaching a thin convex lens of focal length 0.3 m with a speed of 0.01 m/s. Find the magnitudes of the rates of change of position and lateral magnification of image when the object is at a distance of 0.4 m from the lens. [JEE 2004]

Q.28 The ratio of powers of a thin convex and thin concave lens is $\frac{3}{2}$ and equivalent focal length of their combination is 30 cm. Then their focal lengths respectively are [JEE' 2005 (Scr)]
(A) 75, – 50 (B) 75, 50 (C) 10, – 15 (D) – 75, 50

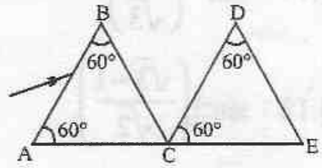
Q.29 Figure shows object O. Final image I is formed after two refractions and one reflection is also shown in figure. Find the focal length of mirror. (in cm) :
(A) 10 (B) 15 (C) 20 (D) 25
[JEE' 2005 (Scr)]



Q.30 What will be the minimum angle of incidence such that the total internal reflection occurs on both the surfaces?
[JEE 2005]



Q.31 Two identical prisms of refractive index $\sqrt{3}$ are kept as shown in the figure. A light ray strikes the first prism at face AB. Find,
(a) the angle of incidence, so that the emergent ray from the first prism has minimum deviation.
(b) through what angle the prism DCE should be rotated about C so that the final emergent ray also has minimum deviation.
[JEE 2005]



ANSWER KEY

EXERCISE # I

Q.1 60°
Q.2 $\sqrt{3}$
Q.3 1.3
Q.4 15 cm
Q.5 45°
Q.6 1.5
Q.7 1000 m/s
Q.8 $x = \dfrac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}, y = \dfrac{\delta(f_1 - d)}{f_1 + f_2 - d}$
Q.9 2 cm
Q.10 80 m/s
Q.11 $\tan^{-1} \dfrac{2}{\sqrt{3}}$ with the principal axis, $\dfrac{\sqrt{7}}{4}$ cm/sec
Q.12 d/2
Q.13 42 cm
Q.14 $\sin^{-1}\left(\dfrac{1}{\sqrt{3}}\right)$
Q.15 $\dfrac{(-4\hat{i} - 3\hat{j})}{5}$
Q.16 42 cm
Q.17 45°
Q.18 $\sin^{-1}\left(\dfrac{\sqrt{3}-1}{\sqrt{2}}\right)$
Q.19 4/3
Q.20 5 cm
Q.21 2h
Q.22 1.70 m
Q.23 15 cm
Q.24 11 cm
Q.25 $\dfrac{apq}{(q-p)}$
Q.26 20 cm behind the mirror
Q.27 (5f, 2d)
Q.28 $(\pi/4)$ cm^2
Q.29 1 cm
Q.30 $\dfrac{\sqrt{43}}{5}$

EXERCISE # II

Q.2 5.9 cm, 10.9 cm
Q.3 f = – 21 cm, $\mu = 1.4$
Q.4 16 feet
Q.5 15 cm towards the combination
Q.6 1.5 or $(\sqrt{5}-1)$
Q.8 8/5 cm/s
Q.10 5/8 – 0.625 cm
Q.11 $r = \dfrac{r_0}{\sqrt{\{1-(r_0/R)^2\}\{n^2-(r_0/R)^2\}+(r_0/R)^2}} = \dfrac{r_0}{n}$, if $r_0 << R$
Q.12 $6\sqrt{26}$ cm
Q.13 (a) 21 m/s, (b) 1×10^{-3} /sec
Q.14 (a) 3.3 cm, (b) $l = (50/3)$ cm
Q.17 $d/2f\theta$

EXERCISE # III

Q.1 (a) $\tan\theta = \dfrac{dy}{dx} = \cot i$ (b) $y = k^2\left(\dfrac{x}{4}\right)^4$ (c) 4.0, 1 (d) It will become parallel to x-axis

Q.2 (i) $\sin^{-1}\left[\dfrac{1}{\sqrt{2}}\left(\sqrt{n^2 - n_1^2} - n_1\right)\right]$ (ii) $r_1 = \sin^{-1}(n \sin 45°) = 72.94°$

Q.3 f = 0.4 m, separation = 0.6 m
Q.4 B, C
Q.5 On the object itself
Q.6 (i) B, (ii) 90 cm from the lens towards right
Q.7 (i) D, (ii) C, D, (iii) A

Q.8 (i) $\lambda_0 = 600$ nm, $n = 1.5$ (ii) $i = \sin^{-1}(0.75) = 48.59°$

Q.9 $\left(\frac{r}{R}\right)_{max} = \frac{1}{2}$

Q.10 A

Q.11 $\vec{r} = \frac{3}{5\sqrt{2}}\hat{i} + \frac{2\sqrt{2}}{5}\hat{j} - \frac{1}{\sqrt{2}}\hat{k}$ (angle of incidence $= 60^0$; $r = 45^0$)

Q.12 m = 4/3

Q.13 $f_1 = -70$cm, $f_2 = 70$cm, V = 560 cm to the right of L_2

Q.14 (a) B (b) A (c) D (d) D

Q.15 A′B′ at 15 cm to the right of mirror. B′ is 0.3 cm above RS and A′ is 1.5 cm below RS. Magnification is 1.5

Q.16 1.6

Q.17 4^0 and -0.04^0

Q.18 B

Q.19 C

Q.20 B

Q.21 A

Q.22 $f = v = \frac{\mu_3 R}{\mu_3 - \mu_1}$

Q.23 A

Q.24 B

Q.25 C

Q.26 $\frac{1.514 \times 0.4}{0.1} = 6.06$ m correct upto two places of decimal.

Q.27 Magnitude of the rate of change of lateral magnification is 0.3 s^{-1}.

Q.28 C

Q.29 C

Q.30 Max $(c_1, c_2) = 60°$

Q.31 (a) $i = 60°$, (b) 60° (anticlockwise)

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

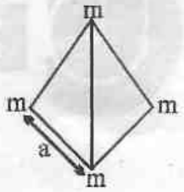
GRAVITATION

CONTENTS

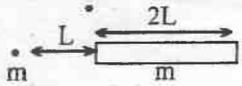
EXERCISE-I

Q.1 A remote sensing satellite is revolving in an orbit of radius x the equator of earth. Find the area on earth surface in which satellite can not send message.

Q.2 Four masses (each of m)are placed at the vertices of a regular pyramid (triangular base) of side 'a'. Find the work done by the system while taking them apart so that they form the pyramid of side '2a'.



Q.3 A small mass and a thin uniform rod each of mass ' m ' are positioned along the same straight line as shown. Find the force of gravitational attraction exerted by the rod on the small mass.



Q.4 An object is projected vertically upward from the surface of the earth of mass M with a velocity such that the maximum height reached is eight times the radius R of the earth. Calculate:
(i) the initial speed of projection
(ii) the speed at half the maximum height.

Q.5 A satellite close to the earth is in orbit above the equator with a period of rotation of 1.5 hours. If it is above a point P on the equator at some time, it will be above P again after time________.

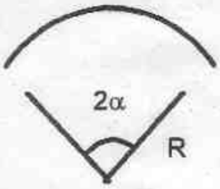
Q.6 A satellite is moving in a circular orbit around the earth. The total energy of the satellite is $E = -2\times10^5$J. The amount of energy to be imparted to the satellite to transfer it to a circular orbit where its potential energy is $U = -2\times10^5$J is equal to ________.

Q.7 A rocket starts vertically upwards with speed v_0. Show that its speed v at a height h is given by

$$v_0^2 - v^2 = \frac{(2gh)}{\left(1+\frac{h}{r}\right)}$$

where R is the radius of the earth. Hence deduce the maximum height reached by a rocket fired with speed equal to 90% of escape velocity.

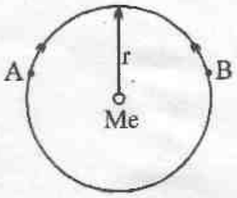
Q.8 Find the gravitational field strength and potential at the centre of arc of linear mass density λ subtending an angle 2α at the centre.



Q.9 A point P lies on the axis of a fixed ring of mass M and radius a, at a distance a from its centre C. A small particle starts from P and reaches C under gravitational attraction only. Its speed at C will be_______.

Q.10 Calculate the distance from the surface of the earth at which above and below the surface acceleration due to gravity is the same.

Q.11 Consider two satellites A and B of equal mass m, moving in the same circular orbit of radius r around the earth E but in opposite sense of rotation and therefore on a collision course (see figure).



(a) In terms of G, M_e, m and r find the total mechanical energy $E_A + E_B$ of the two satellite plus earth system before collision.

(b) If the collision is completely inelastic so that wreckage remains as one piece of tangled material (mass = 2m), find the total mechanical energy immediately after collision.

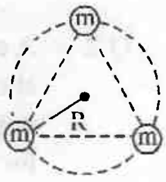
(c) Describe the subsequent motion of the wreckage.

Q.12 A particle is fired vertically from the surface of the earth with a velocity $k\upsilon_e$, where υ_e is the escape velocity and k < 1. Neglecting air resistance and assuming earth's radius as R_e. Calculate the height to which it will rise from the surface of the earth.

Q.13 A satellite of mass m is orbiting the earth in a circular orbit of radius r. It starts losing energy due to small air resistance at the rate of C J/ s. Then the time taken for the satellite to reach the earth is ______.

Q.14 Find the potential energy of a system of eight particles placed at the vertices of a cube of side L. Neglect the self energy of the particles.

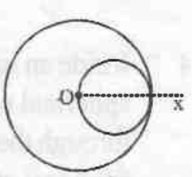
Q.15 A hypothetical planet of mass M has three moons each of equal mass 'm' each revolving in the same circular orbit of radius R. The masses are equally spaced and thus form an equilateral triangle. Find:



(i) the total P.E. of the system
(ii) the orbital speed of each moon such that they maintain this configuration.

Q.16 Two small dense stars rotate about their common centre of mass as a binary system with the period 1year for each. One star is of double the mass of the other and the mass of the lighter one is $\frac{1}{3}$ of the mass of the sun. Find the distance between the stars if distance between the earth & the sun is R.

Q.17 A sphere of radius R has its centre at the origin. It has a uniform mass density ρ_0 except that there is a spherical hole of radius r=R/2 whose centre is at x=R/2 as in fig. (a) Find gravitational field at points on the axis for x > R (ii) Show that the gravitational field inside the hole is uniform, find its magnitude and direction.



Q.18 A body moving radially away from a planet of mass M, when at distance r from planet, explodes in such a way that two of its many fragments move in mutually perpendicular circular orbits around the planet. What will be

(a) then velocity in circular orbits.
(b) maximum distance between the two fragments before collision and
(c) magnitude of their relative velocity just before they collide.

Q.19 The fastest possible rate of rotation of a planet is that for which the gravitational force on material at the equator barely provides the centripetal force needed for the rotation. (Why?)

(a) Show then that the corresponding shortest period of rotation is given by

$$T = \sqrt{\frac{3\pi}{G\rho}}$$

Where ρ is the density of the planet, assumed to be homogeneous.

(b) Evaluate the rotation period assuming a density of 3.0 gm/cm^2, typical of many planets, satellites, and asteroids. No such object is found to be spinning with a period shorter than found by this analysis.

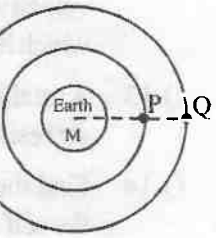
Q.20 A thin spherical shell of total mass M and radius R is held fixed. There is a small hole in the shell. A mass m is released from rest a distance R from the hole along a line that passes through the hole and also through the centre of the shell. This mass subsequently moves under the gravitational force of the shell. How long does the mass take to travel from the hole to the point diametrically opposite.

List of recommended questions from I.E. Irodov.

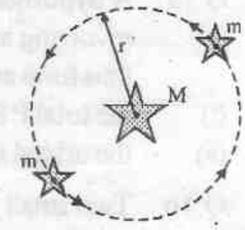
1.213, 1.216 to 1.220, 1.224 to 1.227, 1.229

EXERCISE-II

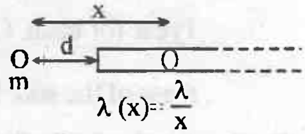
Q.1 A satellite P is revolving around the earth at a height h = radius of earth (R) above equator. Another satellite Q is at a height 2h revolving in opposite direction. At an instant the two are at same vertical line passing through centre of sphere. Find the least time of after which again they are in this situation.



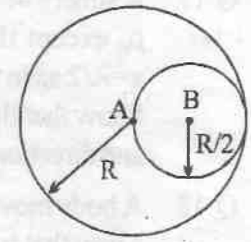
Q.2 A certain triple-star system consists of two stars, each of mass m, revolving about a central star, mass M, in the same circular orbit. The two stars stay at opposite ends of a diameter of the circular orbit, see figure. Derive an expression for the period of revolution of the stars; the radius of the orbit is r.



Q.3 Find the gravitational force of interaction between the mass m and an infinite rod of varying mass density λ such that $\lambda(x) = \lambda/x$, where x is the distance from mass m. Given that mass m is placed at a distance d from the end of the rod on its axis as shown in figure.



Q.4 Inside an isolated fixed sphere of radius R and uniform density r, there is a spherical cavity of radius R/2 such that the surface of the cavity passes through the centre of the sphere as in figure. A particle of mass m is released from rest at centre B of the cavity. Calculate velocity with which particle strikes the centre A of the sphere.



Q.5 In a certain double star system the two stars rotate in circular orbits about their common centre of mass. The stars are spherical, they have same density ρ and their radii arc R and 2 R. Their centres are 5 R apart. Find the period T of stars in terms of ρ, R & G.

Q.6 A ring of radius R is made from a thin wire of radius r. If ρ is the density of the material of wire then what will be the gravitational force exerted by the ring on the material particle of mass m placed on the axis of ring at a distance x from its centre. Show that the force will be maximum when $x = R/\sqrt{2}$ and the maximum value of force will be given as

$$F_{max} = \frac{4\pi^2 G r^2 \rho m}{(3)^{3/2} R}$$

Q.7 In a particular double star system, two stars of mass 3.22×10^{30} kg each revolve about their common center of mass, 1.12×10^{11} m away.

(a) Calculate their common period of revolution, in years.

(b) Suppose that a meteoroid (small solid particle in space) passes through this centre of mass moving at right angles to the orbital plane of the stars. What must its speed be if it is to escape from the gravitational field of the double star?

Q.8 A man can jump over b=4m wide trench on earth. If mean density of an imaginary planet is twice that of the earth, calculate its maximum possible radius so that he may escape from it by jumping. Given radius of earth = 6400 km.

Q.9 A launching pad with a spaceship is moving along a circular orbit of the moon , whose radius R is triple that of moon Rm. The ship leaves the launching pad with a relative velocity equal to the launching pad's initial orbital velocity $\vec{v}_0$ and the launching pad then falls to the moon . Determine the angle θ with the horizontal at which the launching pad crashes into the surface if its mass is twice that of the spaceship m.

Q.10 A small satellite revolves around a heavy planet in a circular orbit. At certain point in its orbit a sharp impulse acts on it and instantaneously increases its kinetic energy to 'k' (< 2) times without change in its direction of motion. Show that in its subsequent motion the ratio of its maximum and minimum distances from the planet is $\frac{k}{2-k}$, assuming the mass of the satellite is negligibly small as compared to that of the planet.

Q.11 A satellite of mass m is in an elliptical orbit around the earth of mass M (M>>m) The speed of the satellite at its nearest point to the earth (perigee) is $\sqrt{\frac{6GM}{5R}}$ where R=its closest distance to the earth. It is desired to transfer this satellite into a circular orbit around the earth of radius equal its largest distance from the earth. Find the increase in its speed to be imparted at the apogee (farthest point on the elliptical orbit).

Q.12 A body is launched from the earth's surface a an angle $\alpha=30^o$ to the horizontal at a speed $v_0=\sqrt{\frac{1.5GM}{R}}$. Neglecting air resistance and earth's rotation, find (a) the height to which the body will rise. (ii) The radius of curvature of trajectory at its top point.

Q.13 Assume that a tunnel is dug across the earth (radius = R) passing through its centre. Find the time a particle takes to reach centre of earth if it is projected into the tunnel from surface of earth with speed needed for it to escape the gravitational field of earth.

EXERCISE-III

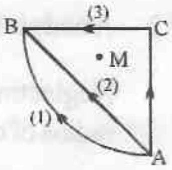
Q.1 If the distance between the earth and the sun were half its present value, the number of days in a year would have been [JEE' 96]
(A) 64.5 (B) 129 (C) 182.5 (D) 730

Q.2 Distance between the centres of two stars is 10 a. The masses of these stars are M and 16 M and their radii a and 2a respectively. A body of mass m is fired at night from the surface of the larger star towards the smaller star. What should be its minimum initial speed to reach the surface of the smaller star ? Obtain the expression in terms of G, M and a. [JEE' 96]

Q.3 An artificial satellite moving in a circular orbit around the earth has a total (K.E. + P.E.) E_0. Its potential energy is [JEE' 97]
(A) $-E_0$ (B) $1.5\ E_0$ (C) $2\ E_0$ (D) E_0

Q.4 A cord of length 64 m is used to connect a 100 kg astronaut to spaceship whose mass is much larger than that of the astronaut. Estimate the value of the tension in the cord. Assume that the spaceship is orbiting near earth surface. Assume that the spaceship and the astronaut fall on a straight line from the earth centre. The radius of the earth is 6400 km. [REE 98]

Q.5 In a region of only gravitational field of mass 'M' a particle is shifted from A to B via three different paths in the figure. The work done in different paths are W_1, W_2, W_3 respectively then



(A) $W_1 = W_2 = W_3$ (B) $W_1 > W_2 > W_3$ (C) $W_1 = W_2 > W_3$ (D) $W_1 < W_2 < W_3$
[JEE' (Scr.) 2003]

Q.6 A body is projected vertically upwards from the bottom of a crater of moon of depth R/100 where R is the radius of moon with a velocity equal to the escape velocity on the surface of moon. Calculate maximum height attained by the body from the surface of the moon. [JEE' 2003]

Q.7 A system of binary stars of masses m_A and m_B are moving in circular orbits of radii r_A and r_B respectively. If T_A and T_B are the time periods of masses m_A and m_B respectively, then [JEE 2006]
(A) $T_A > T_B$ (if $r_A > r_B$) (B) $T_A > T_B$ (if $m_A > m_B$)
(C) $\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$ (D) $T_A = T_B$

ANSWER KEY

EXERCISE-I

Q.1 $\left(1-\frac{\sqrt{x^2-R^2}}{x}\right)4\pi R^2$ Q.2 $-\frac{3Gm^2}{a}$ Q.3 $\frac{G\,m^2}{3\,L^2}$ Q.4 (i) $\frac{4}{3}\sqrt{\frac{Gm}{R}}$, (ii) $\frac{2}{3}\sqrt{\frac{2Gm}{5R}}$

Q.5 1.6 hours if it is rotating from west to east, 24/17 hours if it is rotating from west to east

Q.6 1×10^5J Q.7 $\frac{81}{19}R$ Q.8 $\frac{2G\lambda}{R}(\sin\alpha), (-G\lambda\, 2\alpha)$ Q.9 $\sqrt{\frac{2GM}{a}\left(1-\frac{1}{\sqrt{2}}\right)}$

Q.10 $h=\frac{\sqrt{5}-1}{2}R$ Q.11 (a) $-GmM_e/r$, (b) $-2GmM_e/r$ Q.12 $\frac{R_e k^2}{1-k^2}$

Q.13 $t=\frac{GMm}{2C}\left(\frac{1}{R_e}-\frac{1}{r}\right)$ Q.14 $\frac{-4GM^2}{L}\left[3+\frac{3}{\sqrt{2}}+\frac{1}{\sqrt{3}}\right]$

Q.15 (i) $-\frac{3Gm}{R}\left(\frac{m}{\sqrt{3}}+M\right)$, (ii) $\sqrt{\frac{G}{R}\left(\frac{m}{\sqrt{3}}+M\right)}$ Q.16 R

Q.17 $\vec{g}=-\frac{\pi G\rho_0 R^3}{6}\left[\frac{1}{\left(x-\frac{R}{2}\right)^2}-\frac{8}{x^2}\right]\hat{i}$, $\vec{g}=-\frac{2\pi G\rho_0 R}{3}\hat{i}$ Q.18 (a) $\sqrt{\frac{GM}{r}}$; (b) $r\sqrt{2}$; (c) $\sqrt{\frac{2GM}{r}}$

Q.19 (b) 1.9 h Q.20 $2\times\sqrt{R^3/GM}$

EXERCISE-II

Q.1 $\frac{2\pi R^{3/2}(6\sqrt{6})}{\sqrt{GM}\,(2\sqrt{2}+3\sqrt{3})}$ Q.2 $\frac{4\pi r^{3/2}}{\sqrt{G(4M+m)}}$ Q.3 $\frac{Gm\lambda}{2d^2}$ Q.4 $\sqrt{\frac{2}{3}\pi G\rho R^2}$

Q.5 $T=5\sqrt{\frac{5\pi}{3G\rho}}$ Q.7 (a) $T=4\pi\sqrt{\frac{r^3}{Gm}}$, (b) $v=\sqrt{\frac{4Gm}{r}}$ Q.8 $\sqrt{6.4}$km

Q.9 $\cos\theta=\frac{3}{\sqrt{10}}$ Q.11 $\sqrt{\frac{GM}{R}}\left[\sqrt{\frac{2}{3}}-\sqrt{\frac{8}{15}}\right]$

Q.12 **(a)** $h=\left(\frac{\sqrt{7}}{2}+1\right)R$, **(b)** 1.13R Q.13 $T=\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)\sqrt{\frac{R_e}{g}}$

EXERCISE-III

Q.1 B Q.2 $v_{min}=\frac{3}{2}\sqrt{\frac{5GM}{a}}$ Q.3 C Q.4 $T = 3 \times 10^{-2}$ N

Q.5 A Q.6 h = 99R Q.7 D

4

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

GRAVITATION

QUESTIONS FOR SHORT ANSWER

Q.1 Two satellites move along a circular orbit in the same direction at a small distance from each other. A container has to be thrown from the first satellite onto the second one. When will the container reach the second satellite faster: if its is thrown in the direction of motion of the first satellite or in the opposite direction ? The velocity of the container with respect to the satellite u is much less than that of the satellite v.

Q.2 Because the Earth bulges near the equator, the source of the Mississippi River (at about 50°N latitude), although high above sea level, is about 5 km closer to the centre of the Earth than is its mouth (at about 30°N latitude). How can the river flow "uphill" as it flows south?

Q.3 Use qualitative arguments to explain why the following four periods are equal (all are 84 min, assuming a uniform Earth density) :

(a) time of revolution of a satellite just above the Earth's surface
(b) period of oscillation of mail in a tunnel through the Earth
(c) period of a simple pendulum having a length equal to the Earth's radius in a uniform field 9.8 m/s^2
(d) period of an infinite simple pendulum in the Earth's real gravitational field.

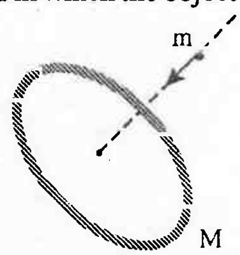
Q.4 After Sputnik I was put into orbit, it was said that it would not return to Earth but would burn up in its descent. Considering the fact that it did not burn up in its ascent, how is this possible ?

Q.5 An artificial satellite is in a circular orbit about the Earth. How will its orbit change if one of its rockets is momentarily fired. (a) towards earth, (b) away from the Earth, (c) in a forward direction, (d) in a backward direction, and (e) at right angles to the plane of the orbit?

Q.6 A stone is dropped along the centre of a deep vertical mine shaft. Assume no air resistance but consider the Earth's rotation. Will the stone continue along the centre of the shaft ? If not, describe its motion.

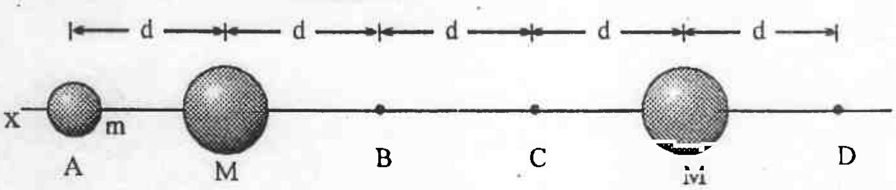
Q.7 An iron cube is placed near an iron sphere at a location remote from the Earth's gravity. What can you say about the location of the centre of gravity of the cube? Of the sphere ? In general, does the location of the centre of gravity of an object depend on the nature of the gravitational field in which the object is placed?

Q.8 Figure shows a particle of mass m that is moved from an infinite distance to the centre of a ring of mass M, along the central axis of the ring. For the trip, how does the magnitude of the gravitational force on the particle due to the ring change.



Q.9 In figure, a particle of mass m is initially at point A, at distance d from the centre of one uniform sphere and distance 4d from the centre of another uniform sphere, both of mass M >> m. State whether, if you moved the particle to point D, the following would be positive, negative, or zero:

(a) the change in the gravitational potential energy of the particle,
(b) the work done by the net gravitational force on the particle,
(c) the work done by your force.
(d) What are the answers if, instead, the move were from point B to point C ?



Q.10 Reconsider the situation of above question. Would the work done by you be positive, negative, or zero if you moved the particle (a) from A to B, (b) from A to C, (c) from B to D ? (d) Rank those moves accroding to the absolute value of the work done by your force, greatest first.

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

Q.1 A large spherical planet of radius R, made of a material of density d, has a spherical cavity of radius R/2, with center of cavity a distance R/2 from the centre of the planet. Find the gravitational force on a small mass 'm' at the center of the cavity.

(A) $2\pi RGmd/3$ (B) $\pi RGmd/3$ (C) $2\pi RGmd$ (D) $4\pi RGmd/3$

Q.2 At what altitude will the acceleration due to gravity be 25% of that at the earth's surface (given radius of earth is R)?

(A) R/4 (B) R (C) 3R/8 (D) R/2

Q.3 At what distance from the centre of the moon is the point at which the strength of the resultant field of earth's and moon's gravitational field is equal to zero. The earth's mass is 81 times that of moon and the distance between centres of these planets is 60R where R is the radius of the earth

(A) 6 R (B) 4 R (C) 3 R (D) 5 R

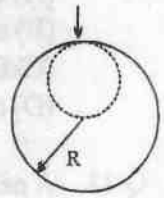
Q.4 Two masses m_1 & m_2 are initially at rest and are separated by a very large distance. If the masses approach each other subsequently, due to gravitational attraction between them, their relative velocity of approach at a separation distance of d is :

(A) $\dfrac{2Gd}{(m_1+m_2)}$ (B) $\dfrac{(m_1+m_2)G}{2d}$ (C) $\left[(m_1+m_2)\dfrac{2G}{d}\right]^{1/2}$ (D) $(m_1+m_2)^{1/2}\,2Gd$

Q.5 Let ω be the angular velocity of the earth's rotation about its axis. Assume that the acceleration due to gravity on the earth's surface has the same value at the equator and the poles. An object weighed at the equator gives the same reading as a reading taken at a depth d below earth's surface at a pole (d<<R) The value of d is

(A) $\dfrac{\omega^2R^2}{g}$ (B) $\dfrac{\omega^2R^2}{2g}$ (C) $\dfrac{2\omega^2R^2}{g}$ (D) $\dfrac{\sqrt{Rg}}{g}$

Q.6 A spherical hole of radius R/2 is excavated from the asteroid of mass M as shown in fig. The gravitational acceleration at a point on the surface of the asteroid just above the excavation is



(A) GM/R^2 (B) $GM/2R^2$ (C) $GM/8R^2$ (D) $7GM/8R^2$

Q.7 If the radius of the earth be increased by a factor of 5, by what factor its density be changed to keep the value of g the same?

(A) 1/25 (B) 1/5 (C) $1/\sqrt{5}$ (D) 5

Q.8 A man of mass m starts falling towards a planet of mass M and radius R. As he reaches near to the surface, he realizes that he will pass through a small hole in the planet. As he enters the hole, he sees that the planet is really made of two pieces a spherical shell of negligible thickness of mass $\dfrac{2M}{3}$ and a point mass $\dfrac{M}{3}$ at the centre. Change in the force of gravity experienced by the man is

(A) $\dfrac{2}{3}\dfrac{GMm}{R^2}$ (B) 0 (C) $\dfrac{1}{3}\dfrac{GMm}{R^2}$ (D) $\dfrac{4}{3}\dfrac{GMm}{R^2}$

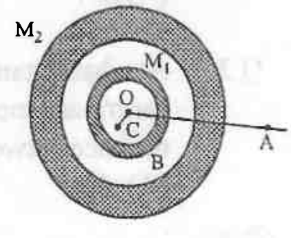
Q.9 An infinite number of masses, each of one kg are placed on the +ve X axis at 1m, 2m, 4m, ______ from the origin. The magnitude of the gravitational field at origin due to this distribution of masses is:

(A) 2G (B) $\frac{4G}{3}$ (C) $\frac{3G}{4}$ (D) ∞

Q.10 With what angular velocity the earth should spin in order that a body lying at 30° latitude may become weightless [R is radius of earth and g is acceleration due to gravity on the surface of earth]

(A) $\sqrt{\frac{2g}{3R}}$ (B) $\sqrt{\frac{4g}{R}}$ (C) $\sqrt{\frac{g}{3R}}$ (D) $\sqrt{\frac{4g}{3R}}$

Q.11 Two concentric shells of uniform density of mass M_1 and M_2 are situated as shown in the figure. The forces experienced by a particle of mass m when placed at positions A, B and C respectively are (given OA = p, OB = q and OC = r)



(A) zero, $G\frac{M_1 m}{q^2}$ and $G\frac{(M_1+M_2)m}{p^2}$

(B) $G\frac{(M_1+M_2)m}{p^2}$, $G\frac{(M_1+M_2)m}{q^2}$ and $G\frac{M_1 m}{r^2}$

(C) $G\frac{M_1 m}{q^2}$, $G\frac{(M_1+M_2)m}{p^2}$ and zero

(D) $G\frac{(M_1+M_2)m}{p^2}$, $G\frac{M_1 m}{q^2}$ and zero

Q.12 A satellite of the earth is revolving in circular orbit with a uniform velocity V. If the gravitational force suddenly disappears, the satellite will

(A) continue to move with the same velocity in the same orbit.
(B) move tangentially to the original orbit with velocity V.
(C) fall down with increasing velocity.
(D) come to a stop somewhere in its original orbit.

Q.13 A newly discovered planet has a density eight times the density of the earth and a radius twice the radius of the earth. The time taken by 2 kg mass to fall freely through a distance S near the surface of the earth is 1 second. Then the time taken for a 4 kg mass to fall freely through the same distance S near the surface of the new planet is

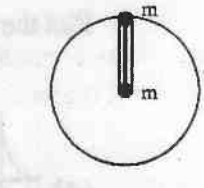
(A) 0.25 sec. (B) 0.5 sec (C) 1 sec. (D) 4 sec.

Q.14 Four particles of equal masses M move along a circle of radius R under the action of their mutual gravitational attraction maintaining a square shape. The speed of each particle is

(A) $\sqrt{\frac{GM}{R}\left(\frac{2\sqrt{2}+1}{4}\right)}$ (B) $\sqrt{\frac{GM}{R}\left(\frac{\sqrt{2}+1}{4}\right)}$ (C) $\sqrt{\frac{GM}{R(\sqrt{2}+1)}}$ (D) $\sqrt{\frac{4GM}{R(\sqrt{2}+1)}}$

Q.15 At what height above the earth's surface does the acceleration due to gravity fall to 1% of its value at the earth's surface?
(A) 9R (B) 10R (C) 99R (D) 100R

Q.16 Find the distance between centre of gravity and centre of mass of a two particle system attached to the ends of a light rod. Each particle has same mass. Length of the rod is R, where R is the radius of earth

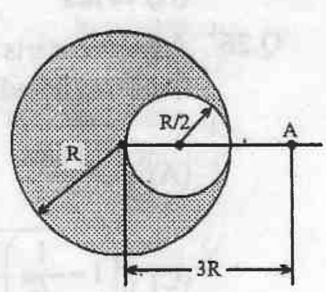


(A) R (B) R/2 (C) zero (D) R/4

Q.17 The radius of a planet is R. A satellite revolves around it in a circle of radius r with angular velocity ω_0. The acceleration due to the gravity on planet's surface is

(A) $\frac{r^3\omega_0}{R}$ (B) $\frac{r^3\omega_0^3}{R^2}$ (C) $\frac{r^3\omega_0^2}{R}$ (D) $\frac{r^3\omega_0^2}{R^2}$

Q.18 A solid sphere of uniform density and radius R applies a gravitational force of attraction equal to F_1 on a particle placed at a distance 3R from the centre of the sphere. A spherical cavity of radius R/2 is now made in the sphere as shown in the figure. The sphere with cavity now applies a gravitational force F_2 on the same particle. The ratio F_2/F_1 is:

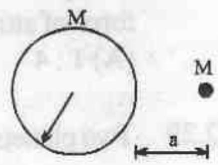


(A) $\frac{9}{50}$ (B) $\frac{41}{50}$ (C) $\frac{3}{25}$ (D) $\frac{22}{25}$

Q.19 The mass and diameter of a planet are twice those of earth. What will be the period of oscillation of a pendulum on this planet if it is a seconds pendulum on earth?

(A) $\sqrt{2}$ second (B) $2\sqrt{2}$ seconds (C) $\frac{1}{\sqrt{2}}$ second (D) $\frac{1}{2\sqrt{2}}$ second

Q.20 A particle of mass M is at a distance a from surface of a thin spherical shell of equal mass and having radius a.



(A) Gravitational field and potential both are zero at centre of the shell.
(B) Gravitational field is zero not only inside the shell but at a point outside the shell also.
(C) Inside the shell, gravitational field alone is zero.
(D) Neither gravitational field nor gravitational potential is zero inside the shell.

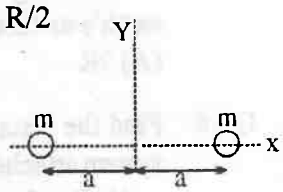
Q.21 Three point masses, M each, are moving in a circle, each with a speed v, under their mutual gravitational attractive force. The distance between any two masses must be:
(A) $2GM/v^2$ (B) $3GM/v^2$ (C) $GM\sqrt{3}/v^2$ (D) GM/v^2

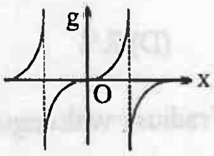
Q.22 A cavity of radius R/2 is made inside a solid sphere of radius R. The centre of the cavity is located at a distance R/2 from the centre of the sphere. Find the gravitational force on a particle of mass 'm' at a distance R/2 from the centre of the sphere on the line joining both the centres of sphere and cavity (opposite to the centre of cavity). [Here $g = GM/R^2$, where M is the mass of the sphere]

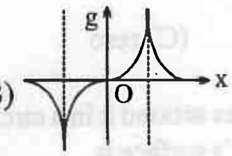
(A) $\frac{mg}{2}$ (B) $\frac{3mg}{8}$ (C) $\frac{mg}{16}$ (D) none of these

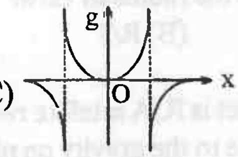
Q.23 How much deep inside the earth should a man go so that his weight becomes one fourth of that at a point which is at a height R above the surface of earth .
(A) R/4 (B) 15R/16 (C) 3R/4 (D) R/2

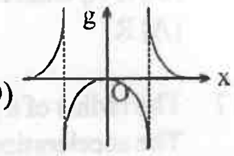
Q.24 Two identical spherical balls each of mass m are placed as shown in figure. Plot the variation of g(gravitation intensity) along the x-axis.



(A) 

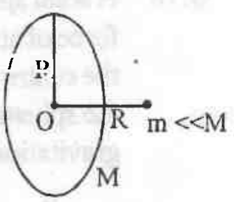
(B) 

(C) 

(D) 

Q.25 A satellite revolves in the geostationary orbit but in a direction east to west. The time interval between its successive passing about a point on the equator is :
(A) 48 hrs (B) 24 hrs (C) 12 hrs (D) never

Q.26 A particle starts from rest at a distance R from the centre and along the axis of a fixed ring of radius R & mass M. Its velocity at the centre of the ring is:



(A) $\sqrt{\frac{\sqrt{2}\,GM}{R}}$ (B) $\sqrt{\frac{2GM}{R}}$

(C) $\sqrt{\left(1-\frac{1}{\sqrt{2}}\right)\frac{GM}{R}}$ (D) $\sqrt{\left(2-\sqrt{2}\right)\frac{GM}{R}}$

Q.27 A spherical uniform planet is rotating about its axis. The velocity of a point on its equator is V. Due to the rotation of planet about its axis the acceleration due to gravity g at equator is 1/2 of g at poles. The escape velocity of a particle on the planet in terms of V.
(A) $V_e = 2V$ (B) $V_e = V$ (C) $V_e = V/2$ (D) $V_e = \sqrt{3}\,V$

Q.28 Two point masses of mass 4*m* and *m* respectively separated by *d* distance are revolving under mutual force of attraction. Ratio of their kinetic energies will be :
(A) 1 : 4 (B) 1 : 5 (C) 1 : 1 (D) 1 : 2

Q.29 Two planets A and B have the same material density. If the radius of A is twice that of B, then the ratio of the escape velocity $\frac{V_A}{V_B}$ is
(A) 2 (B) $\sqrt{2}$ (C) $1/\sqrt{2}$ (D) 1/2

Q.30 The escape velocity on the surface of the earth is V_0. If M and R are the mass and the radius of the earth respectively, then the escape velocity on another planet of mass 2M and radius R/2 will be :
(A) $4\,V_0$ (B) $2\,V_0$ (C) V_0 (D) $V_0/2$

Q.31 A ball 'A' of mass m falls to the surface of the earth from infinity. Another ball 'B' of mass 2m falls to the earth from the height equal to six times radius of the earth then ratio of velocities of 'A' and 'B' on reaching the earth is
(A) √(6/5) (B) √(5/6) (C) 1 (D) √(7/6)

Q.32 If an artificial satellite revolves in circular orbit around the earth with a speed equal to half its escape velocity from the earth. Then its height above the surface of earth will be: [Radius of earth=6400 km]
(A) 3200 km (B) 6400 km (C) 12800 km (D) 24000 km

Q.33 The ratio of gravitational acceleration at height 3R to that at height 4R from the surface of the earth is : (where R is the radius of the earth)
(A) 9/16 (B) 25/16 (C) 16/25 (D) 16/9

Q.34 A small body of superdense material, whose mass is twice the mass of the earth but whose size is very small compared to the size of the earth, starts from rest at a height H<< R above the earth's surface, and reaches the earth's surface in time t. Then t is equal to
(A) $\sqrt{2H/g}$ (B) $\sqrt{H/g}$ (C) $\sqrt{2H/3g}$ (D) $\sqrt{4H/3g}$.

Q.35 A rocket is launched straight up from the surface of the earth. When its altitude is one fourth of the radius of the earth, its fuel runs out and therefore it coasts. The minimum velocity which the rocket must have when it starts to coast if it is to escape from the gravitational pull of the earth is [escape velocity on surface of earth is 11.2km/s]
(A) 1km/s (B) 5km/s (C) 10km/s (D) 15km/s

Q.36 Gravitational potential difference between a point on surface of planet and another point 10m above is 4J/kg. Considering gravitational field to be uniform, how much work is done in moving a mass of 2.0 kg from the surface to a point 5.0m above the surface ?
(A) 0.40 J (B) 2.5 J (C) 4.0 J (D) 8.0 J

Q.37 Referring to **previous problem**, what is the gravitational field strength in this region ?
(A) 0.025 N kg^{-1} (B) 0.40 N kg^{-1} (C) 2.5 Nkg^{-1} (D) 4.0 N kg^{-1}

Q.38 Select the correct choice(s):
(A) The gravitational field inside a spherical cavity, within a spherical planet must be non zero and uniform.
(B) When a body is projected horizontally at an appreciable large height above the earth, with a velocity less than for a circular orbit, it will fall to the earth along a parabolic path.
(C) A body of zero total mechanical energy placed in a gravitational field will escape the field
(D) Earth's satellite must be in equatorial plane .

Q.39 The orbital velocity of an artificial satellite in a circular orbit just above the earth's surface is V_0. The value of orbital velocity for another satellite orbiting at an altitude of half of earth's radius is
(A) $\left(\frac{3}{2}\right)V_0$ (B) $\sqrt{\frac{3}{2}}V_0$ (C) $\sqrt{\frac{2}{3}}V_0$ (D) $\left(\frac{2}{3}\right)V_0$

Q.40 A particle is projected with a velocity $\sqrt{\frac{4gR}{3}}$ vertically upward from the surface of the earth, R being the radius of the earth & g being the acceleration due to gravity on the surface of the earth. The velocity of the particle when it is at half the maximum height reached by it is
(A) $\sqrt{\frac{gR}{2}}$ (B) $\sqrt{\frac{gR}{3}}$ (C) $\sqrt{gR}$ (D) $\sqrt{\frac{2gR}{3}}$

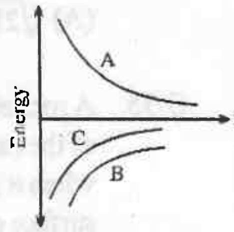
Q.41 A satellite is in a circular orbit very close to the surface of a planet. At some point it is given an impulse along its direction of motion, causing its velocity to increase η times.
It now goes into an elliptical orbit. The maximum possible value of η for this to occur is

(A) 2 (B) $\sqrt{2}$ (C) $\sqrt{2}+1$ (D) $\frac{1}{\sqrt{2}-1}$

Q.42 A satellite of mass m, initially at rest on the earth, is launched into a circular orbit at a height equal to the radius of the earth. The minimum energy required is

(A) $\frac{\sqrt{3}}{4}$ mgR (B) $\frac{1}{2}$ mgR (C) $\frac{1}{4}$ mgR (D) $\frac{3}{4}$ mgR

Q.43 The figure shows the variation of energy with the orbit radius of a body in circular planetary motion. Find the correct statement about the curves A, B and C



(A) A shows the kinetic energy, B the total energy and C the potential energy of the system.
(B) C shows the total energy, B the kinetic energy and A the potential energy of the system.
(C) C and A are kinetic and potential energies respectively and B is the total energy of the system.
(D) A and B are kinetic and potential energies and C is the total energy of the system.

Q.44 The ratio of the radius of the earth to that of the moon is 10. The ratio of the acceleration due to gravity on the earth to that on the moon is 6. The ratio of the escape velocity from the earth's surface to that from the moon is

(A) 6 (B) 1.5 (C) 12 (D) $\sqrt{60}$

Q.45 An artificial satellite of the earth releases a package. If air resistance is neglected, the point where the package will hit (with respect to the position at the time of release) will be
(A) ahead (B) exactly below
(C) behind (D) it will never reach the earth

Q.46 A space ship of mass m is in circular orbit of radius $2R_e$ about the earth of mass M and radius R_e. Energy required to transfer the space ship to circular orbit of radius $3R_e$ is

(A) $\frac{GMm}{8R_e}$ (B) $\frac{GMm}{4R_e}$ (C) $\frac{GMm}{24R_e}$ (D) $\frac{GMm}{12R_e}$

Q.47 A particle is projected from the mid-point of the line joining two fixed particles each of mass m. If the distance of separation between the fixed particles is l, the minimum velocity of projection of the particle so as to escape is equal to

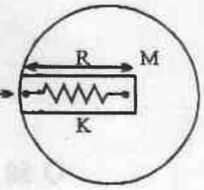
(A) $\sqrt{\frac{GM}{l}}$ (B) $\sqrt{\frac{GM}{2l}}$ (C) $\sqrt{\frac{2GM}{l}}$ (D) $2\sqrt{\frac{2GM}{l}}$

Q.48 The escape velocity for a planet is v_e. A tunnel is dug along a diameter of the planet and a small body is dropped into it at the surface. When the body reaches the centre of the planet, its speed will be

(A) v_e (B) $\frac{v_e}{\sqrt{2}}$ (C) $\frac{v_e}{2}$ (D) zero

Q.49 A per son brings a mass of 1 kg from infinity to a point A. Initially the mass was at rest but it moves at a speed of 2 m/s as it reaches A. The work done by the person on the mass is –3J. The potential at A is :
(A) –3 J/kg (B) –2 J/kg (C) –5 J/kg (D) – 7 J/kg

Q.50 A small ball of mass 'm' is released at a height 'R' above the earth surface, as shown in the figure above. If the maximum depth of the ball to which it goes is R/2 inside the earth through a narrow grove before coming to rest momentarily. The grove, contain an ideal spring of spring constant K and natural length R, find the value of K if R is radius of earth and M mass of earth



(A) $\frac{3GMm}{R^3}$ (B) $\frac{6GMm}{R^3}$
(C) $\frac{9GMm}{R^3}$ (D) $\frac{7GMm}{R^3}$

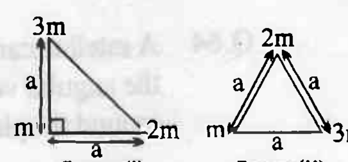
Q.51 The magnitude of the potential energy per unit mass of the object at the surface of earth is E. Then the escape velocity of the object is:
(A) $\sqrt{2E}$ (B) $4E^2$ (C) $\sqrt{E}$ (D) 2E

Q.52 Suppose a smooth tunnel is dug along a straight line joining two points on the surface of the earth and a particle is dropped from rest at its one end. Assume that mass of earth is uniformly distributed over its Volume. Then
(A) the particle will emerge from the other end with velocity $\sqrt{\frac{GM_e}{2R_e}}$ where M_e and R_e are earth's mass and radius respectively,
(B) the particle will come to rest at centre of the tunnel because at this position, particle is closest to earth centre.
(C) potential energy of the particle will be equal to zero at centre of tunnel if it is along a diameter.
(D) acceleration of the particle will be proportional to its distance from midpoint of the tunnel.

Q.53 A hollow spherical shell is compressed to half its radius. The gravitational potential at the centre
(A) increases
(B) decreases
(C) remains same
(D) during the compression increases then returns at the previous value.

Q.54 A body is projection horizontally from the surface of the Earth (radius = R) with a velocity equal to 'n' times the escape velocity. Neglect rotational effects of the earth. The maximum height attained by the body from the Earth's surface is R/2. Then, 'n' must be
(A) $\sqrt{0.6}$ (B) $(\sqrt{3})/2$ (C) $\sqrt{0.4}$ (D) None

Q.55 Consider two configurations of a system of three particles of masses m, 2m and 3m. The work done by external agent in changing the configuration of the system from figure (i) to figure (ii) is



figure(i) figure(ii)

(A) zero (B) $-\frac{6Gm^2}{a}\left(1+\frac{1}{\sqrt{2}}\right)$
(C) $-\frac{6Gm^2}{a}\left(1-\frac{1}{\sqrt{2}}\right)$ (D) $-\frac{6Gm^2}{a}\left(2-\frac{1}{\sqrt{2}}\right)$

Q.56 Two satellites of mass m_1 & m_2 are in same circular orbit around earth but are revolving in opposite sense. When they undergo completely inelastic collision, the combination
(A) continues in same orbit
(B) goes to a circular orbit of lesser radius
(C) goes in an elliptical orbit within the original circle
(D) goes in an elliptical orbit outside the original circle

Q.57 A uniform spherical planet (Radius R) has acceleration due to gravity at its surface g. Points P and Q located inside and outside the planet have acceleration due to gravity $\frac{g}{4}$. Maximum possible separation between P and Q is
(A) $\frac{7R}{4}$ (B) $\frac{3R}{2}$ (C) $\frac{9R}{4}$ (D) none

Q.58 A particle is dropped on Earth from height R (radius of Earth) and it bounces back to a height R/2 the coefficient of restitution for collision is (ignore air resistance and rotation of Earth)
(A) $\frac{2}{3}$ (B) $\sqrt{\frac{2}{3}}$ (C) $\sqrt{\frac{1}{3}}$ (D) $\sqrt{\frac{1}{2}}$

Q.59 A body of mass m is lifted up from the surface of the earth to a height three times the radius of the earth. The change in potential energy of the body is
(A) 3mgR (B) 3/4 mgR (C) 1/3 mgR (D) 2/3 mgR
where g is acceleration due to gravity at the surface of earth.

Q.60 Two satellites S_1 and S_2 describe circular orbits of radius r and 2r respectively around a planet. If the orbital angular velocity of S_1 is ω, that of S_2 is :
(A) $\omega/(2\sqrt{2})$ (B) $(\omega\sqrt{2})/3$ (C) $\omega/2$ (D) $\omega/\sqrt{2}$

Q.61 When a satellite moves around the earth in a certain orbit, the quantity which remains constant is :
(A) angular velocity (B) kinetic energy (C) aerial velocity (D) potential energy

Q.62 A satellite is launched into a circular orbit of radius R around the earth. A second satellite is launched into an orbit of radius 1.02R. The period of second satellite is larger than the first one by approximately
(A) 1.5% (B) 3% (C) 1% (D) 2%

Q.63 A satellite of mass 5M orbits the earth in a circular orbit. At one point in its orbit, the satellite explodes into two pieces, one of mass M and the other of mass 4M. After the explosion the mass M ends up travelling in the same circular orbit, but in opposite direction. After explosion the mass 4M is in
(A) bound orbit
(B) unbound orbit
(C) partially bound orbit
(D) data is insufficient to determine the nature of the orbit.

Q.64 A satellite can be in a geostationary orbit around a planet at a distance r from the centre of the planet. If the angular velocity of the planet about its axis doubles, a satellite can now be in a geostationary orbit around the planet if its distance from the centre of the planet is
(A) $\frac{r}{2}$ (B) $\frac{r}{2\sqrt{2}}$ (C) $\frac{r}{(4)^{1/3}}$ (D) $\frac{r}{(2)^{1/3}}$

Q.65 A planet of mass m is in an elliptical orbit about the sun ($m << M_{sun}$) with an orbital period T. If A be the area of orbit, then its angular momentum would be:
(A) $\frac{2mA}{T}$ (B) mAT (C) $\frac{mA}{2T}$ (D) 2mAT

Q.66 The planets with radii R_1, R_2 have densities ρ_1, ρ_2 respectively. Their atmospheric pressures are p_1, p_2 respectively. Therefore, the ratio of masses of their atmospheres, neglecting variation of g within the limits of atmosphere, is
(A) $p_1R_2\rho_1 / p_2R_1\rho_2$ (B) $p_1R_2\rho_2 / p_2R_1\rho_1$ (C) $p_1R_1\rho_1 / p_2R_2\rho_2$ (D) $p_1R_1\rho_2 / p_2R_2\rho_1$

Q.67 Suppose the gravitational force varies inversely as the nth power of distance. Then the time period of a planet in circular orbit of radius R around the sun will be proportional to
(A) $R^{\left(\frac{n+1}{2}\right)}$ (B) $R^{\left(\frac{n-1}{2}\right)}$ (C) R^n (D) $R^{\left(\frac{n-2}{2}\right)}$

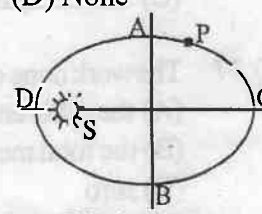
Q.68 A satellite is seen after every 6 hours over the equator. It is known that it rotates opposite to that of earth's direction. Then the angular velocity of the satellite about the centre of earth will be :
(A) $\pi/2$ rad/hr (B) $\pi/3$ rad/hr (C) $\pi/4$ rad/hr (D) $\pi/8$ rad/hr

Q.69 A satellite is orbiting round the earth. In a particular orbit its time period is T and orbital speed is V. In another orbit the orbital speed is 2V, then time period will be
(A) 8T (B) 2T (C) T/2 (D) T/8

Q.70 In a double star system, the masses of the two stars are M and 3M. The orbit radius of the lighter star is R. The time period of each star is
(A) $8\pi[R^3/GM]^{1/2}$ (B) $16\pi[R^3/GM]^{1/2}$ (C) $4\pi[2R^3/GM]^{1/2}$ (D) None

Question No. 71 to 72

Figure shows the orbit of a planet P round the sun S. AB and CD are the minor and major axes of the ellipse.



Q.71 If t_1 is the time taken by the planet to travel along ACB and t_2 the time along BDA, then
(A) $t_1 = t_2$ (B) $t_1 > t_2$ (C) $t_1 < t_2$ (D) nothing can be concluded

Q.72 If U is the potential energy and K kinetic energy then $|U| > |K|$ at
(A) Only D (B) Only C
(C) both D & C (D) neither D nor C

Q.73 If a tunnel is cut at any orientation through earth, then a ball released from one end will reach the other end in time(neglect earth rotation)
(A) 84.6 minutes (B) 42.3 minutes (C) 8 minutes (D) depends on orientation

Questions 74 to 79 (6 questions)

Two stars bound together by gravity orbit each other because of their mutual attraction. Such a pair of stars is referred to as a binary star system. One type of binary system is that of a black hole and a companion star. The black hole is a star that has collapsed on itself and is so massive that not even light rays can escape its gravitational pull. Therefore, when describing the relative motion of a black hole and a companion star, the motion of the black hole can be assumed negligible compared to that of the companion.

The orbit of the companion star is either elliptical with the black hole at one of the foci or circular with the black hole at the centre. The gravitational potential energy is given by $U = -GmM/r$, where G is the universal gravitational constant, m is the mass of the companion star, M is the mass of the black hole, and r is the distance between the centre of the companion star and the centre of the black hole. Since the gravitational force is conservative, the companion star's total mechanical energy is a constant of the motion. Because of the periodic nature of the orbit, there is a simple relation between the average kinetic energy $\langle K \rangle$ of the companion star and its average potential energy $\langle U \rangle$. In particular, $\langle K \rangle = -\langle U/2 \rangle$

Two special points along the orbit are singled out by astronomers. *Perigee* is the point at which the companion star is closest to the black hole, and *apogee* is the point at which it is furthest from the black hole.

Q.74 At which point in the elliptical orbit does the companion star attain its maximum kinetic energy?
(A) Apogee (B) Perigee (C) The point midway from apogee to perigee
(D) All points in the orbit, since the kinetic energy is a constant of the motion.

Q.75 For circular orbits, the potential energy of the companion star is constant throughout the orbit. If the radius of the orbit doubles, what is the new value of the velocity of the companion star?
(A) It is 1/2 of the old value (B) It is $1/\sqrt{2}$ of the old value
(C) It is the same as the old value. (D) It is double the old value

Q.76 Which of the following prevents the companion star from leaving its orbit and falling into the black hole?
(A) The centripetal force (B) The gravitational force
(C) The companion star's potential energy (D) the companion star's kinetic energy

Q.77 The work done on the companion star in one complete orbit by the gravitational force of the black hole equals
(A) the difference in the kinetic energy of the companion star between apogee and perigee.
(B) the total mechanical energy of the companion star
(C) zero
(D) the gravitational force on the companion star times the distance that it travels in one orbit.

Q.78 For a circular orbit, which of the following gives the correct expression for the total energy?
(A) $-(1/2)\,mv^2$ (B) mv^2 (C) $-(GmM)/r$ (D) $(GmM)/2r$

Q.79 What is the ratio of the acceleration of the black hole to that of the companion star?
(A) M / m (B) m / M (C) mM / r (D) 1 / 1

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 Assuming the earth to be a sphere of uniform density the acceleration due to gravity
(A) at a point outside the earth is inversely proportional to the square of its distance from the centre
(B) at a point outside the earth is inversely proportional to its distance from the centre
(C) at a point inside is zero
(D) at a point inside is proportional to its distance from the centre.

Q.2 Mark the correct statement/s
(A) Gravitational potential at curvature centre of a thin hemispherical shell of radius R and mass M is equal to $\frac{GM}{R}$.
(B) Gravitational field strength at a point lying on the axis of a thin, uniform circular ring of radius R and mass M is equal to $\frac{GMx}{(R^2+x^2)^{3/2}}$ where x is distance of that point from centre of the ring.
(C) Newton's law of gravitation for gravitational force between two bodies is applicable only when bodies have spherically symmetric distribution of mass.
(D) None of these.

Q.3 Three particles are projected vertically upward from a point on the surface of the earth with velocities $\sqrt{(2gR/3)}$, $\sqrt{(gR)}$, $\sqrt{(4gR/3)}$ respectively where R is the radius of the earth and g is the acceleration due to gravity on the surface of the earth. The maximum heights attained are respectively h_1, h_2, h_3.
(A) $h_1 : h_2 = 2 : 3$ (B) $h_2 : h_3 = 3 : 4$ (C) $h_1 : h_3 = 1 : 4$ (D) $h_2 = R$

Q.4 A geostationary satellite is at a height h above the surface of earth. If earth radius is R
(A) The minimum colatitude q on earth upto which the satellite can be used for communication is $\sin^{-1}(R/R+h)$.
(B) The maximum colatitudes q on earth upto which the satellite can be used for communication is $\sin^{-1}(R/R+h)$.
(C) The area on earth escaped from this satellite is given as $2pR^2$ (1 + sinq)
(D) The area on earth escaped from this satellite is given as $2pR^2$ (1 + cosq)

Q.5 Gravitational potential at the centre of curvature of a hemispherical bowl of radius R and mass M is V.
(A) gravitational potential at the centre of curvature of a thin uniform wire of mass M, bent into a semicircle of radius R, is also equal to V.
(B) In part (A) if the same wire is bent into a quarter of a circle then also the gravitational potential at the centre of curvature will be V.
(C) In part (A) if the same wire mass is nonuniformly distributed along its length and it is bent into a semicircle of radius R, gravitational potential at the centre is V.
(D) none of these

Q.6 In a solid sphere two small symmetrical cavities are created whose centres lie on a diameter AB of sphere on opposite sides of the centre.
(A) The gravitational field at the centre of the sphere is zero.
(B) The gravitational potential at the centre remains unaffected if cavitiesare not present
(C) A circle at which all points have same potential is in the plane of diameter AB.
(D) A circle at which all points have same potential is in the plane perpendicular to the diameter AB.

Q.7 The spherical planets have the same mass but densities in the ratio 1 : 8. For these planets, the
(A) acceleration due to gravity will be in the ratio 4 : 1
(B) acceleration due to gravity will be in the ratio 1 : 4
(C) escape velocities from their surfaces will be in the ratio $\sqrt{2}$: 1
(D) escape velocities from their surfaces will be in the ratio 1 : $\sqrt{2}$

Q.8 When a satellite in a circular orbit around the earth enters the atmospheric region, it encounters small air resistance to its motion. Then
(A) its kinetic energy increases
(B) its kinetic energy decreases
(C) its angular momentum about the earth decreases
(D) its period of revolution around the earth increases

Q.9 A communications Earth satellite
(A) goes round the earth from east to west
(B) can be in the equatorial plane only
(C) can be vertically above any place on the earth
(D) goes round the earth from west to east

Q.10 An earth satellite is moved from one stable circular orbit to another larger and stable circular orbit. The following quantities increase for the satellite as a result of this change
(A) gravitational potential energy (B) angular vleocity
(C) linear orbital velocity (D) centripetal acceleration

Q.11 Two satellites of same mass of a planet in circular orbits have periods of revolution 32 days and 256 days. If the radius of the orbit of the first is x, then the
(A) radius of the orbit of the second is 8x
(B) radius of the orbit of the second is 4x
(C) total mechanical energy of the second is greater than that of the first
(D) kinetic energy of the second is greater than that of the first.

Q.12 Two satellites s_1 & s_2 of equal masses revolve in the same sense around a heavy planet in coplanar circular orbit of radii R & 4R
(A) the ratio of period of revolution s_1 & s_2 is 1 : 8.
(B) their velocities are in the ratio 2 : 1
(C) their angular momentum about the planet are in the ratio 2 : 1
(D) the ratio of angular velocities of s_2 w.r.t. s_1 when all three are in the same line is 9 : 5.

Q.13 A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth
(A) the acceleration of S is always directed towards the centre of the earth
(B) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant
(C) the total mechanical energy of S varies periodically with time
(D) the linear momentum of S remains constant in magnitude

Q.14 If a satellite orbits as close to the earth's surface as possible,
(A) its speed is maximum
(B) time period of its rotation is minimum
(C) the total energy of the 'earth plus satellite' system is minimum
(D) the total energy of the 'earth plus satellite'system is maximum

Q.15 For a satellite to orbit around the earth, which of the following must be true?
(A) It must be above the equator at some time
(B) It cannot pass over the poles at any time
(C) Its height above the surface cannot exceed 36,000 km
(D) Its period of rotation must be > $2\pi\sqrt{R/g}$ where R is radius of earth

Answer Key

ONLY ONE OPTION IS CORRECT

Q.1	A	Q.2	B	Q.3	A	Q.4	C	Q.5	A	Q.6	B	Q.7	B
Q.8	A	Q.9	B	Q.10	D	Q.11	D	Q.12	B	Q.13	A	Q.14	A
Q.15	A	Q.16	B	Q.17	D	Q.18	B	Q.19	B	Q.20	D	Q.21	D
Q.22	B	Q.23	B	Q.24	A	Q.25	C	Q.26	D	Q.27	A	Q.28	A
Q.29	A	Q.30	B	Q.31	D	Q.32	B	Q.33	B	Q.34	C	Q.35	C
Q.36	C	Q.37	B	Q.38	C	Q.39	C	Q.40	B	Q.41	B	Q.42	D
Q.43	D	Q.44	D	Q.45	D	Q.46	D	Q.47	D	Q.48	B	Q.49	C
Q.50	D	Q.51	A	Q.52	D	Q.53	B	Q.54	A	Q.55	C	Q.56	C
Q.57	C	Q.58	B	Q.59	B	Q.60	A	Q.61	C	Q.62	B	Q.63	B
Q.64	C	Q.65	A	Q.66	D	Q.67	A	Q.68	C	Q.69	D	Q.70	D
Q.71	B	Q.72	C	Q.73	B	Q.74	B	Q.75	B	Q.76	A	Q.77	C
Q.78	A	Q.79	B										

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	A,D	Q.2	B,C	Q.3	C,D	Q.4	A,C
Q.5	A,C	Q.6	A,D	Q.7	B,D	Q.8	A,C
Q.9	B,D	Q.10	A	Q.11	B,C	Q.12	A,B,D
Q.13	A	Q.14	A,B,C	Q.15	A,D		

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (P, Q, R, S)

KINEMATICS

CONTENTS

KEY CONCEPTS

THINGS TO REMEMBER :

1. $v = \frac{ds}{dt}$; $a = \frac{dv}{dt} = v\frac{dv}{ds}$; $s = \int v\,dt$; $v = \int a\,dt$; $\frac{v^2}{2} = \int a\,ds$

   where the symbols have their usual meaning .

2. The equations of motion for a body moving in straight line with uniform acceleration, are

   (i) $v = u + at$ (ii) $s = \left(\frac{u+v}{2}\right)t = ut + \frac{at^2}{2} = vt - \frac{at^2}{2}$ (iii) $v^2 = u^2 + 2as$

   (iv) $s_n = u + \frac{1}{2}a(2n-1)$ (v) $S = \left(\frac{v+u}{2}\right)t$

3. If a body is thrown vertically up with a velocity u in the uniform gravitational field then (neglecting air resistance) :

   (i) Maximum height attained $H = \frac{u^2}{2g}$ (ii) Time of ascent = time of descent = $\frac{u}{g}$

   (iii) Total time of flight = $\frac{2u}{g}$ (iv) Velocity of fall at the point of projection = u downwards

4. **KINEMATIC GRAPH :**

   Slope of the displacement time graph at any particular time gives the magnitude of the instantaneous velocity at that particular time .

   Slope of the v-t graph will give the magnitude of the instantaneous acceleration.

   The area between the v - t graph, the time axis and the ordinates erected at the beginning & end of time interval considered will represent the total displacement of the body.

5. **RELATIVE VELOCITY :**

   (a) Velocity of 'A' relative to 'B' is given by $\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$.

   $\vec{V}_{AB}$ refers to the velocity which 'A' appears to have as seen by B. The above idea of 1 dimensional relative motion can be extended to motion in 2 dimensions.

   (b) Angular velocity of A relative to B i.e. ω_{AB} is given by

   $$\omega_{AB} = \frac{\text{velocity of A relative to B in a direction perpendicular to AB}}{AB}$$

6. **LEVEL GROUND PROJECTILE MOTION :**

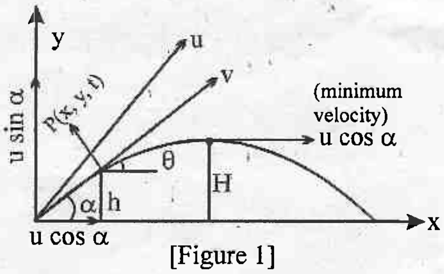
   When a body is thrown obliquely (in a vertical plane) into the uniform gravitational field then the trajectory (actual path of motion) is a parabola. The horizontal component of velocity $u\cos\alpha$ remains unchanged where as vertical component decreases up to the maximum height and then increases .

   (a) Time taken to reach the height point $t_H = \frac{u\sin\alpha}{g}$

   (b) Maximum height $H = \frac{u^2\sin^2\alpha}{2g}$

   (c) Total time of flight = $\frac{2u\sin\alpha}{g} = 2t_H$

   (d) Horizontal range = $(u\cos\alpha).T = \frac{2}{g}(u\cos\alpha)(u\sin\alpha) = \frac{u^2\sin2\alpha}{g}$

   [Figure 1]

   (e) $R_{max} = \frac{u^2}{g}$ if $\alpha = 45°$

   Note that for a given velocity of projection & a given horizontal range there are in general two directions of projection which are complement of each other and are equally inclined to the direction of the maximum range.

(f) **Velocity & Direction Of Motion At A Given Time :**

$$\left.\begin{aligned} V\cos\theta &= u\cos\alpha \\ V\sin\theta &= u\sin\alpha - gt \end{aligned}\right]$$ Squaring & adding these 2 equations we will get the velocity of the projectile. Dividing the velocities in y and x directions gives the direction of motion.

(g) **Velocity & Direction Of Motion At A Given Height h :**

$$\left.\begin{aligned} V^2\cos^2\theta &= u^2\cos^2\alpha \\ V^2\sin^2\theta &= u^2\sin^2\alpha - 2gh \end{aligned}\right] \text{ on adding } V^2 = u^2 - 2gh$$

(h) **Equations Of Motion In Vector Notation :**

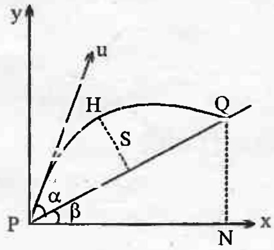
(i) $\vec{V} = \vec{u} + \vec{g}t$ (ii) $\vec{S} = \vec{u}t + \frac{1}{2}\vec{g}t^2$ (iii) $\vec{V}_{av} = \frac{\vec{S}}{t} = \vec{u} + \frac{1}{2}\vec{g}t$ ($\vec{V}_{av}$ = average velocity vector)

(i) **Equation Of Trajectory :**

Oblique Projection (refer fig-1) $y = x\tan\alpha - \frac{gx^2}{2u^2\cos^2\alpha} = x\tan\alpha\left(1 - \frac{x}{R}\right)$

Note that $\frac{dy}{dx}$ represent the direction of motion .

7. PROJECTILE UP AN INCLINED PLANE :



(a) Total time of flight on the inclined plane

$$T = \frac{2u}{g}\frac{\sin(\alpha-\beta)}{\cos\beta}$$

(b) Range PQ on the inclined plane

$$PQ = \frac{2u^2}{g}\frac{\cos\alpha \,.\, \sin(\alpha-\beta)}{\cos^2\beta} = \frac{u^2}{g\cos^2\beta}[\sin(2\alpha-\beta) - \sin\beta]$$

(c) For Maxmimum range $2\alpha - \beta = \frac{\pi}{2} \Rightarrow \alpha = \frac{\pi}{4} + \frac{\beta}{2}$

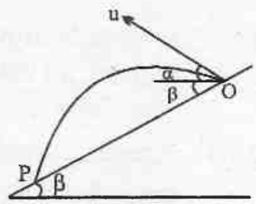
Hence the direction for maximum range bisects the angle between the vertical and the inclined plane .

(d) $R_{max} = \frac{u^2}{g(1+\sin\beta)}$

(e) Greatest distance of the projectile from the inclined plane ;

$S = \frac{u^2\sin^2(\alpha-\beta)}{2g\cos\beta}$ when the projectile is at H, its velocity perpendicular to the plane is zero .

8. PROJECTILE DOWN AN INCLINED PLANE :



(a) Time of flight $= \frac{2u\sin(\alpha+\beta)}{g\cos\beta}$

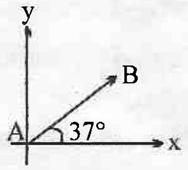
(b) Range OP $= \frac{2u^2\sin(\alpha+\beta)\,.\,\cos\alpha}{g\cos^2\beta}$

(c) Maximum range $= \frac{u^2}{g(1-\sin\beta)}$

(d) Angle of projection α for maximum range $= \frac{\pi}{4} - \frac{\beta}{2}$

EXERCISE – I

Q.1 A butterfly is flying with velocity $10\hat{i}+12\hat{j}$ m/s and wind is blowing along x axis with velocity u. If butterfly starts motion from A and after some time reaches point B, find the value of u.

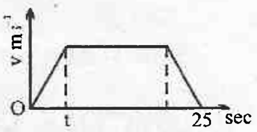


Q.2 Find the change in velocity of the tip of the minute hand (radius = 10 cm) of a clock in 45 minutes.

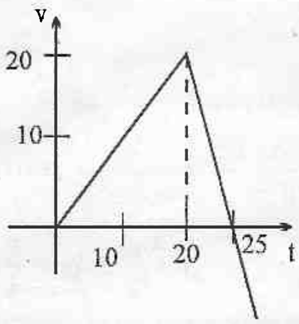
Q.3 A, B & C are three objects each moving with constant velocity. A's speed is 10 m/sec in a direction $\overrightarrow{PQ}$. The velocity of B relative to A is 6 m/sec at an angle of, $\cos^{-1}(15/24)$ to PQ. The velocity of C relative to B is 12 m/sec in a direction $\overrightarrow{QP}$, then find the magnitude of the velocity of C.

Q.4 Rain is falling vertically with a speed of 20 ms^{-1} relative to air. A person is running in the rain with a velocity of 5 ms^{-1} and a wind is also blowing with a speed of 15 ms^{-1} (both towards east). Find the angle with the vertical at which the person should hold his umbrella so that he may not get drenched.

Q.5 The velocity-time graph of the particle moving along a straight line is shown. The rate of acceleration and deceleration is constant and it is equal to 5 ms^{-2}. If the average velocity during the motion is 20 ms^{-1}, then find the value of t.



Q.6 The fig. shows the v–t graph of a particle moving in straight line. Find the time when particle returns to the starting point.



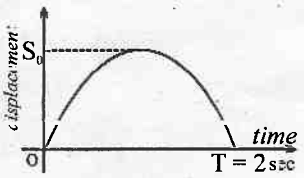
Q.7 A particle is projected in the X-Y plane. 2 sec after projection the velocity of the particle makes an angle 45^0 with the X - axis. 4 sec after projection, it moves horizontally. Find the velocity of projection (use g = 10 ms^{-2}).

Q.8 A small ball rolls off the top landing of a staircase. It strikes the mid point of the first step and then mid point of the second step. The steps are smooth & identical in height & width. Find the coefficient of restitution between the ball & the first step.

Q.9 A stone is dropped from a height h. Simultaneously another stone is thrown up from the ground with such a velocity that it can reach a height of 4h. Find the time when two stones cross each other.

Q.10 A particle is projected upwards with a velocity of 100 m/sec at an angle of 60° with the vertical. Find the time when the particle will move perpendicular to its initial direction, taking g = 10 m/sec^2.

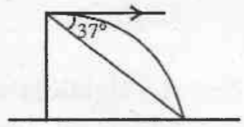
Q.11 A particle is moving on a straight line. Its displacement from the initial position is plotted against time in the graph shown. What will be the velocity of the particle at 2/3 sec? Assume the graph to be a sine curve.



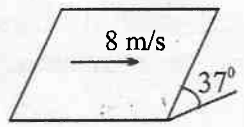
Q.12 A large number of bullets are fired in all direction with the same speed v. What is the maximum area on ground on which these bullets can spread?

Q.13 A boat starts from rest from one end of a bank of a river of width d flowing with velocity u. The boat is steered with constant acceleration a in a direction perpendicular to the bank. If point of start is origin, direction of bank is x axis and perpendicular to bank is y axis. Find the equation of trajectory of the boat.

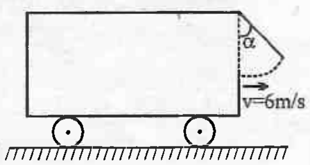
Q.14 A ball is thrown horizontally from a cliff such that it strikes ground after 5 sec. The line of sight from the point of projection to the point of hitting makes an angle of 37° with the horizontal. What is the initial velocity of projection.



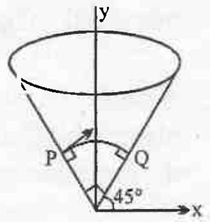
Q.15 A ball is projected on smooth inclined plane in direction perpendicular to line of greatest slope with velocity of 8m/s. Find it's speed after 1 sec.



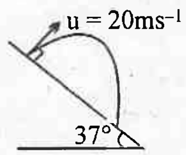
Q.16 A glass wind screen whose inclination with the vertical can be changed, is mounted on a cart as shown in figure. The cart moves uniformly along the horizontal path with a speed of 6 m/s. At what maximum angle α to the vertical can the wind screen be placed so that the rain drops falling vertically downwards with velocity 2 m/s, do not enter the cart?



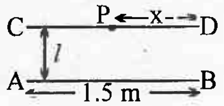
Q.17 A particle is projected from point P with velocity $5\sqrt{2}$ m/s perpendicular to the surface of a hollow right angle cone whose axis is vertical. It collides at Q normally. Find the time of the flight of the particle.



Q.18 Find range of projectile on the inclined plane which is projected perpendicular to the incline plane with velocity 20m/s as shown in figure.

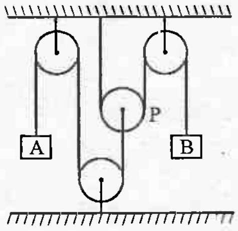


Q.19 AB and CD are two smooth parallel walls. A child rolls a ball along ground from A towards point P find PD so that ball reaches point B after striking the wall CD. Given coefficient of restitution e = 0.5

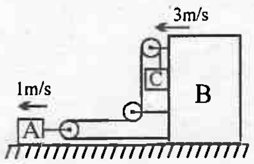


Q.20 Initial acceleration of a particle moving in a straight line is a_0 and initial velocity is zero. The acceleration reduces continuously to half in every t_0 seconds as $a = \dfrac{a_0}{2^{\frac{t}{t_0}}}$. Find the terminal velocity of the particle.

Q.21 Find the acceleration of movable pulley P and block B if acceleration of block A = 1 m/s² ↓.



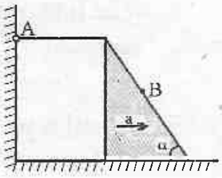
Q.22 The velocities of A and B are marked in the figure. Find the velocity of block C (assume that the pulleys are ideal and string inextensible).



Q.23 A particle is moving in x-y plane such that $x = t + \sin(t)$ meter, $y = \cos(t)$ meter. t is the time in sec. Find the length of the path taken by the particle from $t = 0$ to $t = 2\pi$ sec.

Q.24 The speed of a particle when it is at its greatest height $\sqrt{2/5}$ is of its speed when it is at its half the maximum height. The angle of projection is ______ and the velocity vector angle at half the maximum height is ______ .

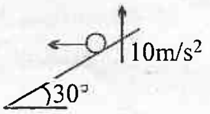
Q.25 A weightless inextensible rope on a stationary wedge forming angle α with the horizontal. One end of the rope is fixed to the wall at point A. A small load is attached to the rope at point B. The wedge starts moving to the right with a constant acceleration. Determine the acceleration a_1 of the load when it is still on the wedge.



Q.26 The horizontal range of a projectiles is R and the maximum height attained by it is H. A strong wind now begins to blow in the direction of motion of the projectile, giving it a constant horizontal acceleration = g/2. Under the same conditions of projection, find the horizontal range of the projectile.

Q.27 Consider the acceleration of a particle for a given time 't' at 'a' m/s^2 followed immediately by retardation at the same rate of 'a' m/s^2 for time 't/2', as one cycle. If the particle started from rest, find the distance travelled by it after 'n' such cycles in succession.

Q.28 A particle is thrown horizontally with relative velocity 10 m/s from an inclined plane, which is also moving with acceleration 10 m/s^2 vertically upward. Find the time after which it lands on the plane ($g = 10\ m/s^2$)



EXERCISE - II

Q.1 A steel ball bearing is released from the roof of a building. An observer standing in front of a window 120 cm high observes that the ball takes 0.125 sec to fall from top to the bottom of the window. The ball continutes to fall & makes a completely elastic collision with side walk & reappears at the bottom of the window 2 s after passing it on the way down. How tall is the building ?

Q.2 A train takes 2 minutes to acquire its full speed 60kmph from rest and 1 minute to come to rest from the full speed. If somewhere in between two stations 1 km of the track be under repair and the limited speed on this part be fixed to 20kmph, find the late running of the train on account of this repair work, assuming otherwise normal at running of the train between the stations.

Q.3 A speeder in an automobile passes a stationary policeman who is hiding behind a bill board with a motorcycle. After a 2.0 sec delay (reaction time) the policeman accelerates to his maximum speed of 150 km/hr in 12 sec and catches the speeder 1.5 km beyond the billboard. Find the speed of speeder in km/hr.

Q.4 A balloon is ascending vertically with an acceleration of $0.2 m/s^2$. Two stones are dropped from it at an interval of 2 sec. Find the distance between them 1.5 sec after the second stone is released.(use $g=9.8 m/s^2$)

Q.5 A ship steaming north at the rate of 12 km/h observes a ship due east to itself and distant 10 km, which steaming due west at the rate of 16 km/h. After what time they are at least distance from one another and what is this least distance.

Q.6 An aeroplane is observed by two persons travelling at 60 km/hr in two vehicles moving in opposite directions on a straight road. To an observer in one vehicle the plane appears to cross the road track at right angles while to the observer in the other vehicle the angle appears to be 45°. At what angle does the plane actually cross the road track and what is its speed relative to the ground.

Q.7 A girl can paddle her canoe at 5m/sec. in still water. She wishes to cross a straight river which is flowing at 3m/sec. At what angle to the river bank should she steer to cross. (a) as quickly as possible. (b) by the shortest route.

Q.8 How long will a plane take to fly around a square with side a with the wind blowing at a velocity u, in the two cases
(a) the direction of the wind coincides with one of the sides
(b) the direction of the wind coincides with one diagonal of the square. The velocity of the plane in still air is $v > u$.

Q.9 Two ships A and B originally at a distance d from each other depart at the same time from a straight coastline. Ship A moves along a straight line perpendicular to the shore while ship B constantly heads for ship A, having at each moment the same speed as the latter. After a sufficiently great interval of time the second ship will obviously follow the first one at a certain distance. Find the distance.

Q.10 The slopes of the wind-screen of two motorcars are $\beta_1 = 30^0$ and $\beta_2 = 15^0$ respectively. The first car is travelling with a velocity of v_1 horizontally. The second car is travelling with a velocity v_2 in the same direction. The hail stones are falling vertically. Both the drivers observe that the hail stones rebound vertically after elastic collision with the wind-screen. Find the ratio of v_1/v_2.

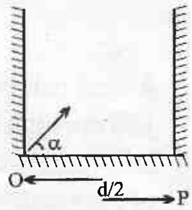
Q.11 A rocket is launched at an angle 53° to the horizontal with an initial speed of $100 ms^{-1}$. It moves along its initial line of motion with an acceleration of $30 ms^{-2}$ for 3 seconds. At this time its engine falls & the rocket proceeds like a free body. Find :
(i) the maximum altitude reached by the rocket
(ii) total time of flight.
(iii) the horizontal range. [sin 53° = 4/5]

Q.12 A small ball is thrown between two vertical walls such that in the absence of the wall its range would have been 5d. The angle of projection is α. Given that all the collisions are perfectly elastic, find

(a) Maximum height attained by the ball.

(b) Total number of collisions before the ball comes back to the ground, and

(c) Point at which the ball falls finally. The walls are supposed to be very tall.



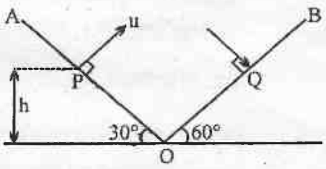
Q.13 A hunter is riding an elephant of height 4m moving in straight line with uniform speed of 2m/sec. A deer running with a speed V in front at a distance of $4\sqrt{5}$m moving perpendicular to the direction of motion of the elephant. If hunter can throw his spear with a speed of 10m/sec. relative to the elephant, then at what angle θ to it's direction of motion must he throw his spear horizontally for a successful hit. Find also the speed 'V' of the deer.

Q.14 A perfectly elastic ball is thrown from the foot of a smooth plane inclined at an angle α to the horizontal. If after striking the plane at a distance l from the point of projection, it rebounds and retraces its former path, show that the velocity of projection is $\sqrt{\dfrac{gl(1+3\sin^2\alpha)}{2\sin\alpha}}$.

Q.15 A particle is projected from the foot of an inclined plane at an angle α in the vertical plane through the line of greatest slope & hits the plane at right angles. If β be the angle the direction of projection makes with the plane & if the particle returns to the point of projection in two jumps, find the value of the coefficient of restitution.

Q.16 A projectile is to be thrown horizontally from the top of a wall of height 1.7 m. Calculate the initial velocity of projection if it hits perpendicularly an incline of angle 37° which starts from the ground at the bottom of the wall. The line of greatest slope of incline lies in the plane of motion of projectile.

Q.17 Two inclined planes OA and OB having inclination (with horizontal) 30° and 60° respectively, intersect each other at O as shown in fig. A particle is projected from point P with velocity $u = 10\sqrt{3}$ m s^{-1} along a direction perpendicular to plane OA. If the particle strikes plane OB perpendicularly at Q, calculate



(a) velocity with which particle strikes the plane OB,

(b) time of flight,

(c) vertical height h of P from O,

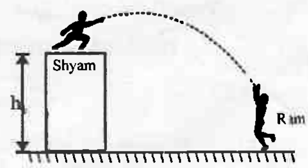
(d) maximum height from O attained by the particle and

(e) distance PQ

Q.18 A particle is projected with a velocity $2\sqrt{ag}$ so that it just clears two walls of equal height 'a' which are at a distance '2a' apart. Show that the time of passing between the walls is $2\sqrt{a/g}$.

Q.19 A stone is projected from the point of a ground in such a direction so as to hit a bird on the top of a telegraph post of height h and then attain the maximum height 2h above the ground. If at the instant of projection, the bird were to fly away horizontally with a uniform speed, find the ratio between the horizontal velocities of the bird and the stone, if the stone still hits the bird while descending.

Q.20 Two persons Ram and Shyam are throwing ball at each other as shown in the figure. The maximum horizontal distance from the building where Ram can stand and still throw a ball at Shyam is d_1. The maximum horizontal distance of Ram from the building where Shyam can throw a ball is d_2. If both of them can throw ball with a velocity of $\sqrt{2gk}$, find the ratio of d_1/d_2. Neglect the height of each person.



EXERCISE # III

Q.1 The motion of a body is given by the equation $\frac{dv(t)}{dt} = 6.0 - 3\,v(t)$; where v (t) is the speed in m/s & t in sec., if the body has v = 0 at t = 0 then

(A) the terminal speed is 2.0 m/s

(B) the magnitude of the initial acceleration is 6.0 m/s²

(C) the speed varies with time as $v(t) = 2(1 - e^{-3t})$ m/s

(D) the speed is 1.0 m/s when the acceleration is half the initial value. [JEE '1995]

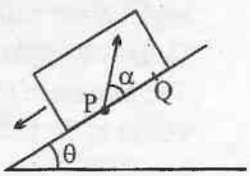
Q.2 Two guns, situated at the top of a hill of height 10 m, fire one shot each with the same speed $5\sqrt{3}$ m/s at some interval of time. One gun fires horizontally and other fires upwards at an angle of 60° with the horizontal. The shots collide in air at a point P. Find

(a) the time interval between the firings, and

(b) the coordinates of the point P. Take origin of the coordinates system at the foot of the hill right below the muzzle and trajectories in X-Y plane. [JEE'1996]

Q.3 The trajectory of a projectile in a vertical plane is $y = ax - bx^2$, where a, b are constants & x and y are respectively the horizontal & vertical distances of the projectile from the point of projection. The maximum height attained is ______ & the angle of projection from the horizontal is ______. [JEE '1997]

Q.4 A large heavy box is sliding without friction down a smooth plane of inclination θ. From a point P on the bottom of a box, a particle is projected inside the box. The initial speed of the particle with respect to box is u and the direction of projection makes an angle α with the bottom as shown in figure.



(a) Find the distance along the bottom of the box between the point of projection P and the point Q where the particle lands. (Assume that the particle does not hit any other surface of the box. Neglect air resistance).

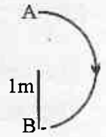
(b) If the horizontal displacement of the particle as seen by an observer on the ground is zero, find the speed of the box with respect to the ground at the instant when the particle was projected. [JEE'1998]

Q.5 A particle of mass 10^{-2} kg is moving slong the positive x-axis under the influence of a force $F(x) = \frac{-K}{2x^2}$ where $K = 10^{-2}$ N m². At time t = 0 it is at x – 1.0 m & its velocity is v = 0 . Find :

(i) its velocity when it reaches x = 0.50 m

(ii) the time at which it reaches x = 0.25 m . [JEE '1998]

Q.6 In 1.0 sec. a particle goes from point A to point B moving in a semicircle of radius 1.0 m. The magnitude of average velocity is : [JEE '99]



(A) 3.14 m/sec (B) 2.0 m/sec

(C) 1.0 m/sec (D) zero

Q.7 The co-ordinates of a particle moving in a plane are given by $x(t) = a\cos(\pi t)$ and $y(t) = b\sin(\pi t)$ where a, b (<a) & π are positive constants of appropriate dimensions.

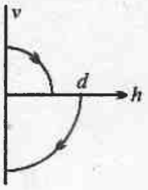
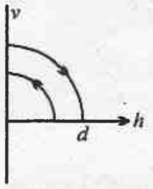
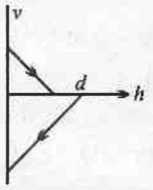
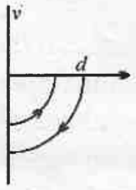
(A) the path of the particle is an ellipse

(B) the velocity & acceleration of the particle are normal to each other at $t = \pi/(2\pi)$

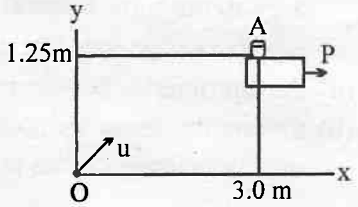
(C) the acceleration of the particle is always directed towards a focus

(D) the distance travelled by the particle in time interval $t = 0$ o $t = \pi/(2\pi)$ is a . [JEE '1999]

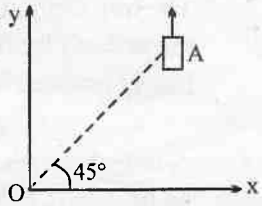
Q.8 A ball is dropped vertically from a height *d* above the ground it hits the ground and bounces up vertically to a height *d*/2. Neglecting subsequent motion and air resistances, its velocity *v* varies with the height *h* above the ground as [JEE'2000 (Scr)]

(A) 
(B) 
(C) 
(D) 

Q.9 An object A is kept fixed at the point x = 3 m and y = 1.25 m on a plank P raised above the ground. At time t = 0 the plank starts moving along the + x direction with an acceleration 1.5 m/s^2. At the same instant a stone is projected from the origin with a velocity u as shown. A stationary person on the ground observes the stone hitting the object during its downward motion at an angle of 45° to the horizontal. All the motions are in x-y plane. Find u and the time after which the stone hits the object. Take g = 10 m/s^2. [JEE 2000]



Q.10 On a frictionless horizontal surface, assumed to be the x-y plane, a small trolley A is moving along a straight line parallel to the y-axis (see figure) with a constant velocity of $(\sqrt{3}-1)$ m/s. At a particular instant, when the line OA makes an angle of 45° with the x-axis, a ball is thrown along the surface from the origin O. Its velocity makes an angle ϕ with the x-axis and it hits the trolley.

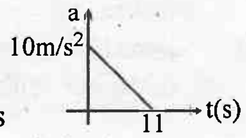


(a) The motion of the ball is observed from the frame of trolley. Calculate the angle θ made by the velocity vector of the ball with the x-axis in this frame.

(b) Find the speed of the ball with respect to the surface, if $\phi = \frac{4\theta}{3}$. [JEE 2002]

Q.11 A particle starts from rest. Its acceleration (a) versus time (t) is as shown in the figure. The maximum speed of the particle will be [JEE' 2004 (Scr)]

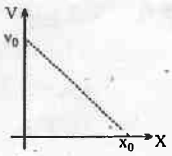
(A) 110 m/s (B) 55 m/s (C) 550 m/s (D) 660 m/s

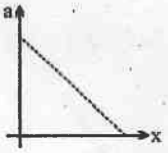
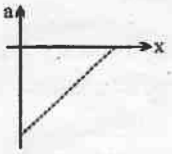
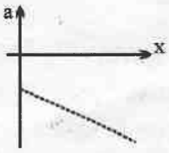
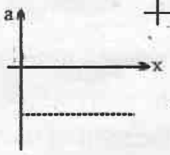


Q.12 A small block slides without friction down an inclined plane starting from rest. Let Sn be the distance travelled from time t = n - 1 to t = n. Then $\frac{S_n}{S_{n+1}}$ is [JEE' 2004 (Scr)]

(A) $\frac{2n-1}{2n}$ (B) $\frac{2n+1}{2n-1}$ (C) $\frac{2n-1}{2n+1}$ (D) $\frac{2n}{2n+1}$

Q.13 The velocity displacement graph of a particle moving along a straight line is shown. The most suitable acceleration-displacement graph will be



(A) 
(B) 
(C) 
(D) 

[JEE' 2005 (Scr)]

ANSWER KEY

EXERCISE # I

Q.1 6 m/s
Q.2 $\left(\frac{\pi\sqrt{2}}{3}\right)$ cm/min
Q.3 5 m/sec
Q.4 $\tan^{-1}(1/2)$
Q.5 5 s
Q.6 36.2 sec.
Q.7 $20\sqrt{5}$
Q.8 3/4
Q.9 $\sqrt{\left(\frac{h}{8g}\right)}$
Q.10 20 sec
Q.11 $\frac{S_0\pi}{4}$
Q.12 $\frac{\pi v^4}{g^2}$
Q.13 $y = \frac{a x^2}{2u^2}$
Q.14 100/3 m/s
Q.15 10 m/s
Q.16 $2\tan^{-1}(1/3)$
Q.17 1 sec
Q.18 75 m
Q.19 1m
Q.20 $\frac{a_0 t_0}{ln(2)}$
Q.21 $a_P = 1\ m/s^2 \downarrow,\ a_B = 2\ m/s^2 \uparrow$
Q.22 5 m/s
Q.23 8 m
Q.24 $60^0, \tan^{-1}\left(\sqrt{3/2}\right)$
Q.25 $2a\sin(\alpha/2)$
Q.26 R + 2H
Q.27 $\frac{n(3n+4)}{8}at^2$
Q.28 $\frac{1}{\sqrt{3}}$ sec

EXERCISE # II

Q.1 20.5 m
Q.2 160 sec
Q.3 122.7 km/hr
Q.4 50m
Q.5 24 min, 6 km
Q.6 $\theta = \tan^{-1}2$, v = 134.16 km/h
Q.7 (a) 90^0, (b) 127^0 to the river flow
Q.8 (a) $\frac{2a\left(v+\sqrt{v^2-u^2}\right)}{v^2-u^2}$, (b) $\frac{2\sqrt{2}a\left(\sqrt{2v^2-u^2}\right)}{v^2-u^2}$
Q.9 $\frac{d}{2}$
Q.10 3
Q.11 (i) 1503.2 m (ii) 35.54 sec (iii) 3970.56 m
Q.12 (a) $5d/4\tan\alpha$, (b) 9, (c) point O
Q.13 $\theta = 37^0$, v = 6m/s
Q.15 $e = \frac{\sqrt{5}-1}{2}$
Q.16 u = 3m/s
Q.17 (a) 10 ms^{-1}, (b) 2 sec, (c) 5 m, (d) 16.25 m, (e) 20 m
Q.19 $\frac{2}{\sqrt{2}+1}$
Q.20 $\sqrt{\frac{k-h}{k+h}}$

EXERCISE # III

Q.1 A, B, C, D
Q.2 (a) 1 sec, (b) ($5\sqrt{3}$ m, 5 m)
Q.3 $\frac{a^2}{4b}$, $\tan^{-1}a$
Q.4 (a) $\frac{u^2\sin 2\alpha}{g\cos\theta}$, (b) $v = \frac{u\cos(\alpha+\theta)}{\cos\theta}$
Q.5 (i) $\vec{V} = -1\ \hat{i}$ m/s (ii) $t = \frac{\pi}{3} + \frac{\sqrt{3}}{4}$
Q.6
Q.7 A, B
Q.8 A
Q.9 u = 7.29 m/s, t = 1 sec
Q.10 (a) 45°, (b) 2 m/sec
Q.11 B
Q.12 C
Q.13 B

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (P,Q,R,S)

IIT-JEE
SCREENING 2007

QUESTION BANK ON

KINEMATICS

Time Limit : 2 Sitting Each of 60 minutes. duration approx.

QUESTION ON KINEMATICS

There are 54 questions in this question bank.

Q.1 A particle is moving along a curve. Then
(A) if its speed is constant it has no acceleration
(B) if its speed is increasing the acceleration of the particle is along its direction of motion
(C) if its speed is constant the magnitude of its acceleration is proportional to its curvature.
(D) the direction of its acceleration cannot be along the tangent.

Q.2 A boat having a speed of 5 km/hr. in still water, crosses a river of width 1 km along the shortest possible path in 15 minutes. The speed of the river in Km/hr.
(A) 1 (B) 3 (C) 4 (D) $\sqrt{41}$

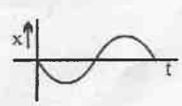
Q.3 A block is thrown with a velocity of 2 ms^{-1} (relative to ground) on a belt, which is moving with velocity 4 ms^{-1} in opposite direction of the initial velocity of block. If the block stops slipping on the belt after 4 sec of the throwing then choose the correct statements (s)
(A) Displacement with respect to ground is zero after 2.66 and displacement with respect to ground is 12 m after 4 sec.
(B) Displacement with respect to ground in 4 sec is 4 m.
(C) Displacement with respect to belt in 4 sec is – 12 m.
(D) Displacement with respect to ground is zero in 8/3 sec.

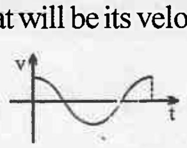
Q.4 A particle has initial velocity 10 m/s. It moves due to constant retarding force along the line of velocity which produces a retardation of 5 m/s^2. Then
(A) the maximum displacement in the direction of initial velocity is 10 m
(B) the distance travelled in first 3 seconds is 7.5 m
(C) the distance travelled in first 3 seconds is 12.5 m
(D) the distance travelled in first 3 seconds is 17.5 m.

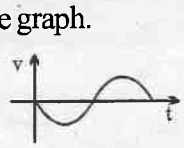
Q.5 The displacement x of a particle depend on time t as $x = \alpha t^2 - \beta t^3$
(A) particle will return to its starting point after time $\frac{\alpha}{\beta}$.
(B) the particle will come to rest after time $\frac{2\alpha}{3\beta}$
(C) the initial velocity of the particle was zero but its initial acceleration was not zero.
(D) no net force act on the particle at time $\frac{\alpha}{3\beta}$

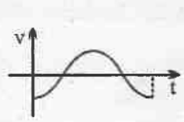
Q.6 A ball is thrown from a point on ground at some angle of projection. At the same time a bird starts from a point directly above this point of projection at a height h horizontally with speed u. Given that in its flight ball just touches the bird at one point. Find the distance on ground where ball strikes
(A) $2u\sqrt{\frac{h}{g}}$ (B) $u\sqrt{\frac{2h}{g}}$ (C) $2u\sqrt{\frac{2h}{g}}$ (D) $u\sqrt{\frac{h}{g}}$

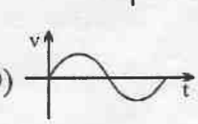
Q.7 If position time graph of a particle is sine curve as shown, what will be its velocity-time graph.



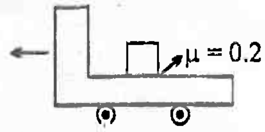
(A)


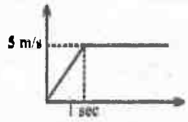
(B)


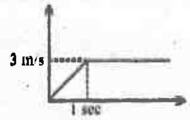
(C)


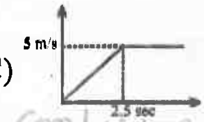
(D)


Q.8 A truck starting from rest moves with an acceleration of 5 m/s^2 for 1 sec and then moves with constant velocity. The velocity w.r.t ground v/s time graph for block in truck is (Assume that block does not fall off the truck)



(A) 

(B) 

(C) 

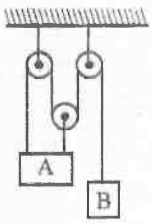
(D) None of these

Q.9 If angular velocity of a disc depends an angle rotated θ as $\omega = \theta^2 + 2\theta$, then its angular acceleration α at θ = 1 rad is :
(A) 8 rad/sec^2 (B) 10 rad/sec^2 (C) 12 rad/sec^2 (D) None

Q.10 Two particles start simultaneously from the same point and move along two straight lines, one with uniform velocity v and other with a uniform acceleration a. If α is the angle between the lines of motion of two particles then the least value of relative velocity will be at time given by
(A) (v/a) sin α (B) (v/a) cos α (C) (v/a) tan α (D) (v/a) cot α

Q.11 If a particle takes t second less and acquires a velocity of v ms^{-1} more in falling through the same distance (starting from rest) on two planets where the accelerations due to gravity are 2 g and 8 g respectively then:
(A) v = 2gt (B) v = 4gt
(C) v = 5 gt (D) v = 16 gt

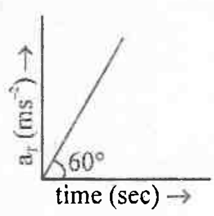
Q.12 At a given instant, A is moving with velocity of 5m/s upwards. What is velocity of B at that time :
(A) 15 m/s ↓ (B) 15 m/s ↑
(C) 5 m/s ↓ (D) 5 m/s ↑



Q.13 It takes one minute for a passenger standing on an escalator to reach the top. If the escalator does not move it takes him 3 minute to walk up . How long will it take for the passenger to arrive at the top if he walks up the moving escalator ?
(A) 30 sec (B) 45 sec (C) 40 sec (D) 35 sec

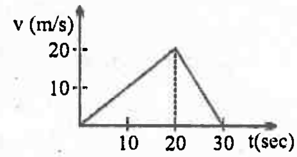
Q.14 The co-ordinates of a moving particle at a time t, are give by, x = 5 sin 10 t, y = 5 cos 10t. The speed of the particle is :
(A) 25 (B) 50 (C) 10 (D) None

Q.15 Tangential acceleration of a particle moving in a circle of radius 1 m varies with time t as (initial velocity of particle is zero). Time after which total acceleration of particle makes and angle of 30° with radial acceleration is
(A) 4 sec (B) 4/3 sec
(C) $2^{2/3}$ sec (D) $\sqrt{2}$ sec



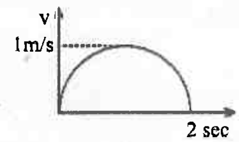
Q.16 A particle is projected from a horizontal plane (x-z plane) such that its velocity vector at time t is given by $\vec{V} = a\hat{i} + (b - ct)\hat{j}$. Its range on the horizontal plane is given by
(A) $\frac{ba}{c}$ (B) $\frac{2ba}{c}$ (C) $\frac{3ba}{c}$ (D) None

Q.17 v-t graph of an object of mass 1 kg is shown
(A) net work done on the object in 30 sec is zero.
(B) the average acceleration of the object is zero.
(C) the average velocity of the object is zero.
(D) the average force on the object is zero.



Q.18 A projectile of mass 1 kg is projected with a velocity of $\sqrt{20}$ m/s such that it strikes on the same level as the point of projection at a distance of $\sqrt{3}$ m. Which of the following options are incorrect:
(A) the maximum height reached by the projectile can be 0.25 m.
(B) the minimum velocity during its motion can be $\sqrt{15}$ m/s
(C) the minimum time taken for the flight can be $\sqrt{\frac{3}{5}}$ sec.
(D) maximum potential energy during its motion can be 6J.

Q.19 Velocity-time graph for a car is semicircle as shown here. Which of the following is correct :
(A) Car must move in circular path.
(B) Acceleration of car is never zero.
(C) Mean speed of the particle is $\pi/2$ m/s.
(D) The car makes a turn once during its motion.



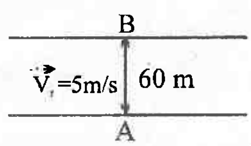
Q.20 A ball is projected from top of a tower with a velocity of 5 m/s at an angle of 53^0 to horizontal. Its speed when it is at a height of 0.45 m from the point of projection is :
(A) 2 m/s (B) 3 m/s (C) 4 m/s (D) data insufficient.

Q.21 A particle moves along a straight line in such a way that it's acceleration is increasing at the rate of 2 m/s^3. It's initial acceleration and velocity were 0, the distance covered by it in t = 3 second is.
(A) 27 m (B) 9 m (C) 3 m (D) 1 m

Q.22 A flag is mounted on a car moving due North with velocity of 20 km/hr. Strong winds are blowing due East with velocity of 20 km/hr. The flag will point in direction
(A) East (B) North - East (C) South - East (D) South - West

Q.23 A ball is thrown vertically down with velocity of 5m/s. With what velocity should another ball be thrown down after 2 seconds so that it can hit the 1st ball in 2 seconds
(A) 40 m/s (B) 55 m/s (C) 15 m/s (D) 25 m/s

Q.24 A man is crossing a river flowing with velocity of 5 m/s. He reaches a point directly across at a distance of 60 m in 5 sec. His velocity in still water should be
(A) 12 m/s (B) 13 m/s
(C) 5 m/s (D) 10 m/s



Q.25 Average velocity of a particle is projectile motion between its starting point and the highest point of its trajectory is : (projection speed = u, angle of projection from horizontal= θ)

(A) $u\cos\theta$ (B) $\frac{u}{2}\sqrt{1+3\cos^2\theta}$ (C) $\frac{u}{2}\sqrt{2+\cos^2\theta}$ (D) $\frac{u}{2}\sqrt{1+\cos^2\theta}$

Q.26 Find time of flight of projectile thrown horizontally with speed 50 ms^{-1} from a long inclined plane which makes an angle of $\theta = 45°$ from horizontal.

(A) $10\sqrt{2}$ sec (B) $20\sqrt{2}$ sec (C) 10 sec (D) $5\sqrt{2}$ sec

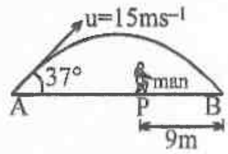
Q.27 Particle is dropped from the height of 20m from horizontal ground. There is wind blowing due to which horizontal acceleration of the particle becomes 6 ms^{-2}. Find the horizontal displacement of the particle till it reaches ground.

(A) 6 m (B) 10 m (C) 12 m (D) 24 m

Q.28 A ball is dropped from height 5m. The time after which ball stops rebounding if coefficient of restitution between ball and ground e = 1/2, is

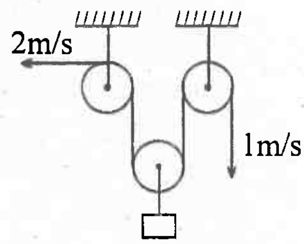
(A) 1 sec (B) 2 sec (C) 3 sec (D) infinite

Q.29 A ball is hit by a batsman at an angle of 37° as shown in figure. The man standing at P should run at what minimum velocity so that he catches the ball before it strikes the ground. Assume that height of man is negligible in comparison to maximum height of projectile.



(A) 3 ms^{-1} (B) 5 ms^{-1}
(C) 9 ms^{-1} (D) 12 ms^{-1}

Q.30 Find the velocity of the hanging block if the velocities of the free ends of the rope are as indicated in the figure.



(A) 3/2 m/s ↑
(B) 3/2 m/s ↓
(C) 1/2 m/s ↑
(D) 1/2 m/s ↓

Q.31 A man swimming down stream overcome a float at a point M. After travelling distance D he turned back and passed the float at a distance of D/2 from the point M, then the ratio of speed of swimmer with respect to still water to the speed of the river will be

(A) 2 (B) 3 (C) 4 (D) 2.5

Q.32 Choose the correct alternative (s)

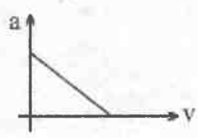
(A) If the greatest height to which a man can throw a stone is h, then the greatest horizontal distance upto which he can throw the stone is 2h.

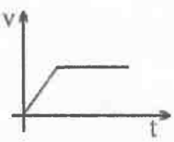
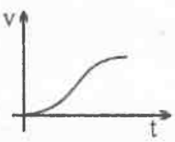
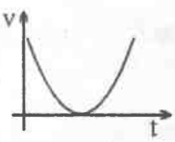
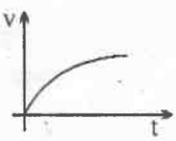
(B) The angle of projection for a projectile motion whose range R is n times the maximum height is $\tan^{-1}(4/n)$

(C) The time of flight T and the horizontal range R of a projectile are connected by the equation $gT^2 = 2R\tan\theta$ where θ is the angle of projection.

(D) A ball is thrown vertically up. Another ball is thrown at an angle θ with the vertical. Both of them remain in air for the same period of time. Then the ratio of heights attained by the two balls 1 : 1.

Q.33 Acceleration versus velocity graph of a particle moving in a straight line starting from rest is as shown in figure. The corresponding velocity-time graph would be



(A)  (B)  (C)  (D) 

Q.34 A particle is projected vertically upwards from a point A on the ground. It takes t_1 time to reach a point B but it still continues to move up. If it takes further t_2 time to reach the ground from point B then height of point B from the ground is

(A) $\frac{1}{2}g(t_1+t_2)^2$ (B) $g\,t_1\,t_2$ (C) $\frac{1}{8}g(t_1+t_2)^2$ (D) $\frac{1}{2}\,g\,t_1\,t_2$

Q.35 Mark the correct statements for a particle going on a straight line
(A) if the velocity is zero at any instant, the acceleration should also be zero at that instant
(B) if the velocity is zero for a time interval, the acceleration is zero at any instant within the time interval
(C) if the velocity and acceleration have opposite sign, the object is slowing down
(D) if the position and velocity have opposite sign, the particle is moving towards the origin

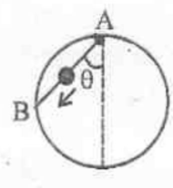
Q.36 A projectile is fired with a speed u at an angle θ with the horizontal. Its speed when its direction of motion makes an angle 'α' with the horizontal is
(A) u secθ cosα (B) u secθ sinα (C) u cosθ secα (D) u sin θ secα

Q.37 Balls are thrown vertically upward in such a way that the next ball is thrown when the previous one is at the maximum height. If the maximum height is 5m, the number of balls thrown per minute will be
(A) 40 (B) 50 (C) 60 (D) 120

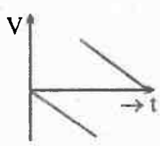
Q.38 A projectile is fired with a velocity at right angle to the slope which is inclined at an angle θ with the horizontal. The expression for the range R along the incline is

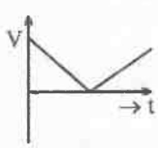
(A) $\frac{2v^2}{g}\sec\theta$ (B) $\frac{2v^2}{g}\tan\theta$ (C) $\frac{2v^2}{g}\tan\theta\sec\theta$ (D) $\frac{v^2}{g}\tan^2\theta$

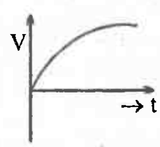
Q.39 A bead is free to slide down a smooth wire tightly stretched between points A and B on a vertical circle. If the bead starts from rest at A, the highest point on the circle
(A) its velocity v on arriving at B is proportional to cosθ
(B) its velocity v on arriving at B is proportional to tanθ
(C) time to arrive at B is proportional to cosθ
(D) time to arrive at B is independent of θ

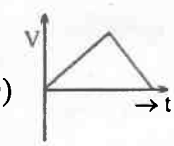


Q.40 The velocity- time graph of a body falling from rest under gravity and rebounding from a solid surface is represented by which of the following graphs?

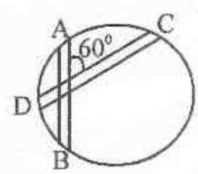
(A) 

(B) 

(C) 

(D) 

Q.41 A disc arranged in a vertical plane has two groves of same length directed along the vertical chord AB and CD as shown in the fig. The same particles slide down along AB and CD. The ratio of the time t_{AB}/t_{CD} is



(A) 1 : 2 (B) 1 : $\sqrt{2}$ (C) 2 : 1 (D) $\sqrt{2}$: 1

Q.42 The magnitude of displacement of a particle moving in a circle of radius a with constant angular speed ω varies with time t as

(A) 2 a sinωt (B) $2a\sin\frac{\omega t}{2}$ (C) 2a cos ωt (D) $2a\cos\frac{\omega t}{2}$

Q.43 A glass wind screen whose inclination with the vertical can be changed is mounted on a car. The car moves horizontally with a speed of 2m/s. At what angle α with the vertical should the wind screen be placed so that the rain drops falling vertically downwards with velocity 6 m/s strike the wind screen perpendicularly.

(A) $\tan^{-1}(3)$ (B) $\tan^{-1}(1/3)$ (C) $\cos^{-1}(3)$ (D) $\sin^{-1}(1/3)$

Q.44 A particle is projected vertically upwards from O with velocity v and a second particle is projected at the same instant from P (at a height h above O) with velocity v at an angle of projection θ. The time when the distance between them is minimum is

(A) $\frac{h}{2v\sin\theta}$ (B) $\frac{h}{2v\cos\theta}$ (C) h/v (D) h/2v

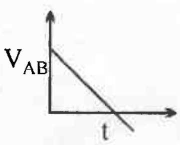
Q.45 A body moves with velocity $v = \ell n\, x$ m/s where x is its position. The net force acting on body is zero at :

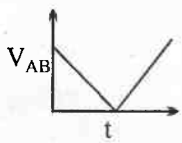
(A) 0 m (B) $x = e^2$ m (C) $x = e$ m (D) $x = 1$ m

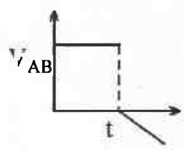
Q.46 Wind is blowing in the north direction at speed of 2 m/s which causes the rain to fall at some angle with the vertical. With what velocity should a cyclist drive so that the rain appears vertical to him :

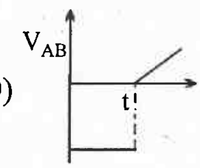
(A) 2 m/s south (B) 2 m/s north (C) 4 m/s west (D) 4 m/s south

Q.47 A body A is thrown vertically upwards with such a velocity that it reaches a maximum height of h. Simultaneously another body B is dropped from height h. It strikes the ground and does not rebound. The velocity of A relative to B v/s time graph is best represented by : (upward direction is positive)

(A) 

(B) 

(C) 

(D) 

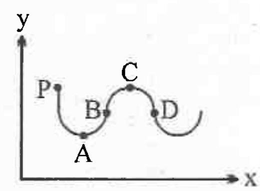
Q.48 A body of mass 1 kg is acted upon by a force $\vec{F} = 2\sin 3\pi t\,\hat{i} + 3\cos 3\pi t\,\hat{j}$ find its position at t = 1 sec if at t = 0 it is at rest at origin.

(A) $\left(\frac{3}{3\pi^2}, \frac{2}{9\pi^2}\right)$ (B) $\left(\frac{2}{3\pi^2}, \frac{2}{3\pi^2}\right)$ (C) $\left(\frac{2}{3\pi}, \frac{2}{3\pi^2}\right)$ (D) none of these

Q.49 A force $F = Be^{-Ct}$ acts on a particle whose mass is m and whose velocity is 0 at t = 0. It's terminal velocity is :

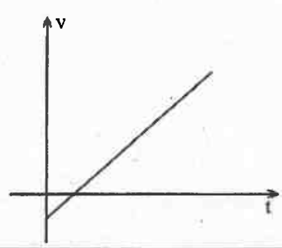
(A) $\frac{C}{mB}$ (B) $\frac{B}{mC}$ (C) $\frac{BC}{m}$ (D) $-\frac{B}{mC}$

Q.50 A man moves in x-y plane along the path shown. At what point is his average velocity vector in the same direction as his instantaneous velocity vector. The man starts from point P.



(A) A (B) B (C) C (D) D

Q.51 From the velocity time garph of a particle moving in straight line decide which of the following is incorrect statement .



(A) the particle crosses its initial position
(B) the speed of the particle increases continuously
(C) the force on the particle is constant
(D) the acceleration of the particle is constant.

Q.52 If T is the total time of flight, h is the maximum height & R is the range for horizontal motion, the x & y co-ordinates of projectile motion and time t are related as :

(A) $y = 4h\left(\frac{t}{T}\right)\left(1-\frac{t}{T}\right)$ (B) $y = 4h\left(\frac{X}{R}\right)\left(1-\frac{X}{R}\right)$

(C) $y = 4h\left(\frac{T}{t}\right)\left(1-\frac{T}{t}\right)$ (D) $y = 4h\left(\frac{R}{X}\right)\left(1-\frac{R}{X}\right)$

Q.53 A particle initially at rest is subjected to two forces . One is constant, the other is a retarding force proportional to the particle velocity . In the subsequent motion of the particle :

(A) the acceleration will increase from zero to a constant value
(B) the acceleration will decrease from its initial value to zero
(C) the velocity will increase from zero to maximum & then decrease
(D) the velocity will increase from zero to a constant value.

Q.54 A ball is projected from ground with a velocity V at an angle θ to the vertical. On its path it makes an elastic collison with a vertical wall and returns to ground. The total time of flight of the ball is

(A) $\frac{2v\sin\theta}{g}$ (B) $\frac{2v\cos\theta}{g}$ (C) $\frac{v\sin 2\theta}{g}$ (D) $\frac{v\cos\theta}{g}$

ANSWER KEY

Q.1	C, D	Q.2	B	Q.3	B, C, D	Q.4	A, C
Q.5	A, B, C, D	Q.6	C	Q.7	C	Q.8	C
Q.9	C	Q.10	B	Q.11	B	Q.12	A
Q.13	B	Q.14	B	Q.15	C	Q.16	B
Q.17	A, B, D	Q.18	D	Q.19	C	Q.20	C
Q.21	B	Q.22	C	Q.23	A	Q.24	B
Q.25	B	Q.26	C	Q.27	C	Q.28	C
Q.29	B	Q.30	A	Q.31	B	Q.32	A, B, C, D
Q.33	D	Q.34	D	Q.35	B, C, D	Q.36	C
Q.37	C	Q.38	C	Q.39	A, D	Q.40	A
Q.41	B	Q.42	B	Q.43	A	Q.44	D
Q.45	D	Q.46	B	Q.47	C	Q.48	C
Q.49	B	Q.50	C	Q.51	B	Q.52	A, B
Q.53	B, D	Q.54	B				

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

MAGNETIC EFFECT OF CURRENT

CONTENTS

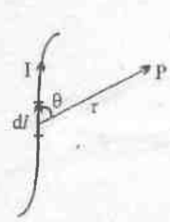
KEY CONCEPTS

1. A static charge produces only electric field and only electric field can exert a force on it.
A moving charge produces both electric field ans magnetic field and both electric field and magnetic field can exert force on it.
A current carrying conductor produces only magnetic field and only magnetic field can exert a force on it.

2. Magnetic charge (i.e. current), produces a magnetic field. It can not produce electric field as net charge on a current carrying conductor is zero. A magnetic field is detected by its action on current carrying conductors (or moving charges) and magnetic needles (compass) needles. The vector quantity $\vec{B}$ known as MAGNETIC INDUCTION is introduced to characterise a magnetic field. It is a vector quantity which may be defined in terms of the force it produces on electric currents. Lines of magnetic induction may be drawn in the same way as lines of electric field. The number of lines per unit area crossing a small area perpendicular to the direction of the induction bring numerically equal to $\vec{B}$. The number of lines of $\vec{B}$ crossing a given area is referred to as the MAGNETIC FLUX linked with that area. For this reason $\vec{B}$ is also called MAGNETIC FLUX DENSITY.

3 **MAGNETIC INDUCTION PRODUCED BY A CURRENT (BIOT-SAVART LAW):**
The magnetic induction dB produced by an element $d\ell$ carrying a current I at a distance r is given by :

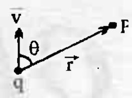
$$dB = \frac{\mu_0 \mu_r}{4\pi} \frac{I d\ell \sin\theta}{r^2} \quad \text{or} \quad \vec{dB} = \frac{\mu_0 \mu_r}{4\pi} \frac{I(d\vec{\ell} \times \vec{r})}{r^3},$$



here the quantity $Id\ell$ is called as current element strength.
μ = permeability of the medium $= \mu_0 \mu_r$, μ_0 = permeability of free space
μ_r = relative permeability of the medium (Dimensionless quantity).
Unit of μ_0 & μ is NA^{-2} or Hm^{-1}; $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$

4 **MAGNETIC INDUCTION DUE TO A MOVING CHARGE**

$$dB_P = \frac{\mu_0 q v \sin\theta}{4\pi r^2}$$



In vector form it can be written as $\vec{dB} = \frac{\mu_0}{4\pi} \frac{q(\vec{v} \times \vec{r})}{r^3}$

5. **MAGNETIC INDUCTION DUE TO AN INIFINITE ST. CONDUCTOR**

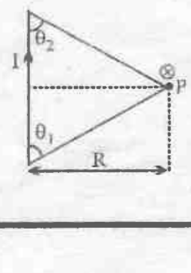
$$B = \frac{\mu_0 I}{2\pi r}$$

6. **MAGNETIC INDUCTION DUE TO SEMI INIFINITE ST. CONDUCTOR**

$$B = \frac{\mu_0 I}{4\pi r}$$

7. **MAGNETIC INDUCTION DUE TO A CURRENT CARRYING STRAIGHT CONDUCTOR**

$$B = \frac{\mu_0 I}{4\pi R}(\cos\theta_1 + \cos\theta_2)$$



If the wire is very long $\theta_1 = \theta_2 = 0°$ then, $B = \frac{\mu_0 I}{2\pi R}$

8. MAGNETIC FIELD DUE TO A FLAT CIRCULAR COIL CARRYING A CURRENT :



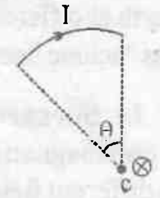
(i) At its centre $B = \dfrac{\mu_0 NI}{2R}$, direction $\odot$

Where N = total number of turns in the coil
I = current in the coil
R = Radius of the coil

(ii) On the axis $B = \dfrac{\mu_0 NIR^2}{2\left(x^2+R^2\right)^{3/2}}$

Where x = distance of the point from the centre . It is maximum at the centre .

9. MAGNETIC INDUCTION DUE TO FLAT CIRCULAR ARC

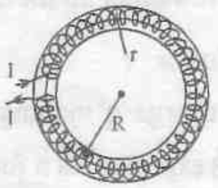


$$B = \frac{\mu_0 I\theta}{4\pi R}$$

10. MAGNETIC INDUCTION DUE TO SOLENOID

$B = \mu_0 nI$, direction along axis.
where n → no. of turns per m.
I → current

11. MAGNETIC INDUCTION DUE TO TOROID



$B = \mu_0 nI$

where $n = \dfrac{N}{2\pi R}$ (no. of turns per m)

N = total turns R >> r

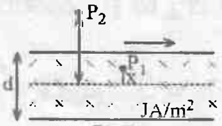
12. MAGNETIC INDUCTION DUE TO CURRENT CARRYING SHEET



$$B = \frac{1}{2}\mu_0 I$$

where I = Linear current density (A/m)

13. MAGNETIC INDUCTION DUE TO THICK SHEET



At point P_2 $B_{out} = \dfrac{1}{2}\mu_0 Id$

At point P_1 $B_{in} = \mu_0 Jx$

14. MAGNETIZATION INTENSITY (H) :

The magnetic intensity (H) at any point in a magnetic field is defined as $\vec{H} = \dfrac{\vec{B}}{\mu}$, where

B = magnetic induction at the point ; μ = permeability of the medium

15. GILBERT'S MAGNETISM (EARTH'S MAGNETIC FIELD) :

(a) The line of earth's magnetic induction lies in a vetical plane coinciding with the magnetic North - South direction at that place. This plane is called the MAGNETIC MERIDIAN. Earth's magnetic axis is slightly inclined to the geometric axis of earth and this angle varies from 10.5^0 to 20^0. The Earth's Magnetic poles are opposite to the geometric poles i.e. at earth's north pole, its magnetic south pole is situated and vice versa.

(b) On the magnetic meridian plane, the magnetic induction vector of the earth at any point, generally inclined to the horizontal at an angle called the **MAGNETIC DIP** at that place, such that $\vec{B}$ = total magnetic induction of the earth at that point.

$\vec{B}_V$ = the vertical component of $\vec{B}$ in the magnetic meridian plane = B sin θ .

B_H = the horizontal component of $\vec{B}$ in the magnetic meridian plane = B cos θ .

$\frac{B_V}{B_H} = \tan\theta$.

(c) At a given place on the surface of the earth, the magnetic meridian and the geographic meridian may not coincide. The angle between them is called "**DECLINATION AT THAT PLACE**" .

(d) Lines drawn on earth at different places having same declination angle are called as "isogonic lines" and line of zero declination is called as "agonic lines".

(e) Lines drawn on earth at different places having same dip angle are called as "isoclinic lines" and line of zero dip is called as "aclinic lines".

16. NEUTRAL POINT IN SUPERPOSED MAGNETIC FIELDS :

When more than one magnetic fields are suspended at a point and the vector sum of the magnetic inductions due to different fields, equal to zero, the point is a magnetic neutral point.

17 AMPERES LAW $\oint \vec{B}\cdot d\vec{\ell} = \mu\Sigma I$

Σ I = algebric sum of all the currents .

18. LORENTZ FORCE :

An electric charge 'q' moving with a velocity $\vec{V}$ through a magnetic field of magnetic induction $\vec{B}$ experiences a force $\vec{F}$, given by $\vec{F} = q\vec{V}\times\vec{B}$. There fore, if the charge moves in a space where both electric and magnetic fields are superposed .

$\vec{F}$ = nett electromagnetic force on the charge = $q\vec{E} + q\vec{V}\times\vec{B}$

This force is called the **LORENTZ FORCE .**

19. MOTION OF A CHARGE IN UNIFORM MAGNETIC FIELD :

(a) When $\vec{v}$ is || to $\vec{B}$: Motion will be in a st. line and $\vec{F} = 0$

(b) When $\vec{v}$ is ⊥ to $\vec{B}$: Motion will be in circular path with radius $R = \frac{mv}{q\vec{B}}$ and angular velocity $\omega = \frac{qB}{m}$ and F = qvB.

(c) When $\vec{v}$ is at ∠θ to $\vec{B}$: Motion will be helical with radius $R_⊥ = \frac{mv\sin\theta}{qB}$ and pitch $P_H = \frac{2\pi mv\cos\theta}{qB}$ and F = qvBsinθ.

20. MAGNETIC FORCE ON A STRAIGHT CURRENT CARRYING WIRE :

$\vec{F} = I(\vec{L}\times\vec{B})$

I = current in the straight conductor

$\vec{L}$ = length of the conductor in the direction of the current in it

$\vec{B}$ = magnetic induction. (Uniform throughout the length of conduction)

Note : In general force is $\vec{F} = \int I(d\vec{\ell}\times\vec{B})$

21. MAGNETIC INTERACTION FORCE BETWEEN TWO PARALLEL LONG STRAIGHT CURRENTS :

When two long straight linear conductors are parallel and carry a current in each , they magnetically interact with each other , one experiences a force. This force is of :

(i) Repulsion if the currents are anti-parallel (i.e. in opposite direction) or

(ii) Attraction if the currents are parallel (i.e. in the same direction)

This force per unit length on either conductor is given by $F = \frac{\mu_0}{2\pi}\frac{I_1I_2}{r}$. Where r – perpendicular distance between the parallel conductors

22. MAGNETIC TORQUE ON A CLOSED CURRENT CIRCUIT :

When a plane closed current circuit of 'N' turns and of area 'A' per turn carrying a current I is placed in uniform magnetic field , it experience a zero nett force , but experience a torque given by $\vec{\tau} = NI\vec{A}\times\vec{B} = \vec{M}\times\vec{B} = BINA\sin\theta$

When $\vec{A}$ = area vector outward from the face of the circuit where the current is anticlockwise,

$\vec{B}$ = magnetic induction of the uniform magnetic feild. $\vec{M}$ = magnetic moment of the current circuit = $IN\vec{A}$

Note : This expression can be used only if $\vec{B}$ is uniform otherwise calculus will be used.

23. MOVING COIL GALVANOMETER :

It consists of a plane coil of many turns suspended in a radial magnetic feild. when a current is passed in the coil it experiences a torque which produces a twist in the suspension. This deflection is directly proportional to the torque $\therefore$ NIAB = Kθ

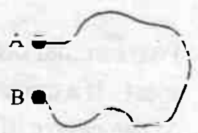
$I = \left(\frac{K}{NAB}\right)\theta$ K = elastic torsional constant of the suspension

$I = C\ \theta$ $C = \frac{K}{NAB}$ = GALVANOMETER CONSTANT.

24. FORCE EXPERIENCED BY A MAGNETIC DIPOLE IN A NON-UNIFORM MAGNETIC FIELD :

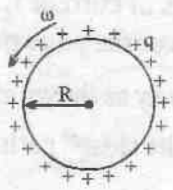
$|\vec{F}| = \left|M\frac{\partial B}{\partial r}\right|$ where M = Magnetic dipole moment.

25. FORCE ON A RANDOM SHAPED CONDUCTOR IN MAGNETIC FIELD



1. Magnetic force on a loop in a uniform $\vec{B}$ is zero
2. Force experienced by a wire of any shape is equivalent to force on a wire joining points A & B in a uniform magnetic field .

26. MAGNETIC MOMENT OF A ROTATING CHARGE:



If a charge q is rotating at an angular velocity ω,

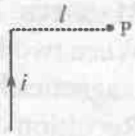
its equivalent current is given as $I = \frac{q\omega}{2\pi}$ & its

magnetic moment is $M = I\pi R^2 = \frac{1}{2}q\omega R^2$.

NOTE: The rate of magnetic moment to Angular momentum of a uniform rotating object which is charged uniformly is always a constant. Irrespective of the shape of conductor $\frac{M}{L} = \frac{q}{2m}$

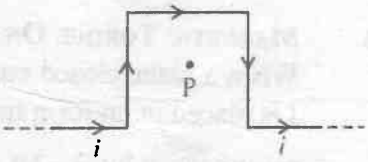
EXERCISE # I

Q.1 Figure shows a straight wire of length l carrying a current i. Find the magnitude of magnetic field produced by the current at point P.

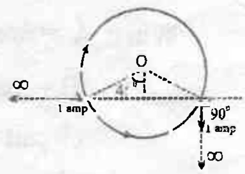


Q.2 Two circular coils A and B of radius $\frac{5}{\sqrt{2}}$ cm and 5 cm respectively carry current 5 Amp and $\frac{5}{\sqrt{2}}$ Amp respectively. The plane of B is perpendicular to plane of A and their centres coincide. Find the magnetic field at the centre.

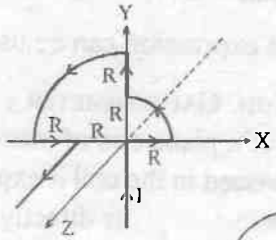
Q.3 Find the magnetic field at the centre P of square of side a shown in figure



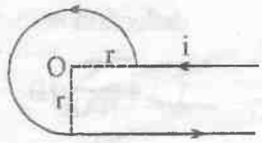
Q.4 What is the magnitude of magnetic field at the centre 'O' of loop of radius $\sqrt{2}$ m made of uniform wire when a current of 1 amp enters in the loop and taken out of it by two long wires as shown in the figure.



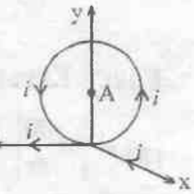
Q.5 Find the magnetic induction at the origin in the figure shown.



Q.6 Find the magnetic induction at point O, if the current carrying wire is in the shape shown in the figure.

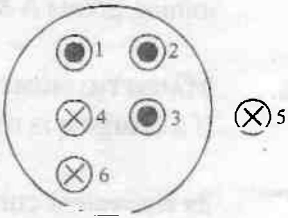


Q.7 Find the magnitude of the magnetic induction B of a magnetic field generated by a system of thin conductors along which a current i is flowing at a point A (O, R, O), that is the centre of a circular conductor of radius R. The ring is in yz plane.



Q.8 Two circular coils of wire each having a radius of 4 cm and 10 turns have a common axis and are 6 cm apart. If a current of 1 A passes through each coil in the opposite direction find the magnetic induction.
(i) At the centre of either coil ;
(ii) At a point on the axis, midway between them.

Q.9 Six wires of current $I_1 = 1A$, $I_2 = 2A$, $I_3 = 3A$, $I_4 = 1A$, $I_5 = 5A$ and $I_6 = 4A$ cut the page perpendicularly at the points 1, 2, 3, 4, 5 and 6 respectively as shown in the figure. Find the value of the integral $\oint \vec{B} \cdot d\vec{l}$ around the closed path.



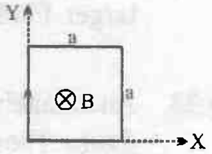
Q.10 Electric charge q is uniformly distributed over a rod of length l. The rod is placed parallel to a long wire carrying a current i. The separation between the rod and the wire is a. Find the force needed to move the rod along its length with a uniform velocity v.

Q.11 An electron moving with a velocity $5 \times 10^6\ ms^{-1}\ \hat{i}$ in the uniform electric field of $5 \times 10^7\ Vm^{-1}\ \hat{j}$. Find the magnitude and direction of a minimum uniform magnetic field in tesla that will cause the electron to move undeviated along its original path.

Q.12 A charged particle (charge q, mass m) has velocity v_0 at origin in +x direction. In space there is a uniform magnetic field B in - z direction. Find the y coordinate of particle when is crosses y axis.

Q.13 A conducting circular loop of radius r carries a constant current i. It is placed in a uniform magnetic field $\vec{B}_0$ such that $\vec{B}_0$ is perpendicular to the plane of the loop. Find the magnetic force acting on the loop is

Q.14 A rectangular loop of wire is oriented with the left corner at the origin, one edge along X-axis and the other edge along Y-axis as shown in the figure. A magnetic field is into the page and has a magnitude that is given by $\beta = \alpha y$ where α is contant. Find the total magnetic force on the loop if it carries current i.



Q.15 Two coils each of 100 turns are held such that one lies in the vertical plane with their centres coinciding. The radius of the vertical coil is 20 cm and that of the horizontal coil is 30 cm. How would you neutralize the magnetic field of the earth at their common centre? What is the current to be passed through each coil? Horizontal component of earth's magnetic induction = 3.49×10^{-5} T and angle of dip = 30°.

Q.16 Find the ratio of magnetic field magnitudes at a distance 10 m along the axis and at 60° from the axis, from the centre of a coil of radius 1 cm, carrying a current 1 amp.

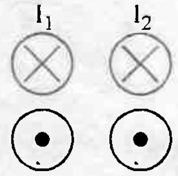
Q.17 A particle of charge +q and mass m moving under the influence of a uniform electric field $E\hat{i}$ and a magnetic field $B\hat{k}$ enters in I quadrant of a coordinate system at a point (0, a) with initial velocity $v\hat{i}$ and leaves the quadrant at a point (2a, 0) with velocity $-2v\hat{j}$. Find

(a) Magnitude of electric field

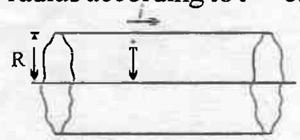
(b) Rate of work done by the electric field at point (0, a)

(c) Rate of work done by both the fields at (2a, 0).

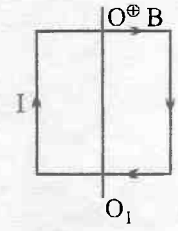
Q.18 A system of long four parallel conductors whose sections with the plane of the drawing lie at the vertices of a square there flow four equal currents. The directions of these currents are as follows:
those marked ⊗ point away from the reader, while those marked with a dot point towards the reader. How is the vector of magnetic induction directed at the centre of the square?



Q.19 A cylindrical conductor of radius R carries a current along its length. The current density J, however, it is not uniform over the cross section of the conductor but is a function of the radius according to J = br, where b is a constant. Find an expression for the magnetic field B.
(a) at $r_1 < R$ & (b) at distance $r_2 > R$, mesured from the axis



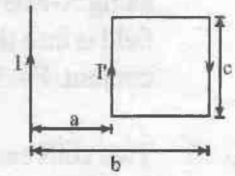
Q.20 A square current carrying loop made of thin wire and having a mass m = 10g can rotate without friction with respect to the vertical axis OO_1, passing through the centre of the loop at right angles to two opposite sides of the loop. The loop is placed in a homogeneous magnetic field with an induction $B = 10^{-1}$ T directed at right angles to the plane of the drawing. A current I = 2A is flowing in the loop. Find the period of small oscillations that the loop performs about its position of stable equilibrium.



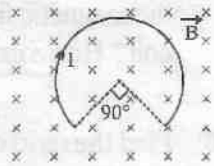
Q.21 A charged particle having mass m and charge q is accelerated by a potential difference V, it flies through a uniform transverse magnetic field B. The field occupies a region of space d. Find the time interval for which it remains inside the magnetic field.

Q.22 A proton beam passes without deviation through a region of space where there are uniform transverse mutually perpendicular electric and magnetic field with E and B. Then the beam strikes a grounded target. Find the force imparted by the beam on the target if the beam current is equal to I.

Q.23 An infinitely long straight wire carries a conventional current I as shown in the figure. The rectangular loop carries a conventional current I' in the clockwise direction. Find the net force on the rectangular loop.



Q.24 An arc of a circular loop of radius R is kept in the horizontal plane and a constant magnetic field B is applied in the vertical direction as shown in the figure. If the arc carries current I then find the force on the arc.



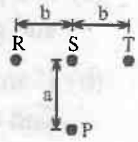
Q.25 Two long straight parallel conductors are separated by a distance of r_1 = 5cm and carry currents i_1 = 10 A & i_2 = 20 A. What work per unit length of a conductor must be done to increase the separation between the conductors to r_2 = 10 cm if, currents flow in the same direction?

List of recommended questions from I.E. Irodov.

3.220, 3.223, 3.224, 3.225, 3.226, 3.227, 3.228, 3.229, 3.230, 3.234, 3.236, 3.237, 3.242 3.243, 3.244, 3.245, 3.251, 3.252, 3.253, 3.254, 3.257, 3.258, 3.269, 3.372, 3.373, 3.383, 3.384, 3.386, 3.389, 3.390, 3.391, 3.396

EXERCISE # II

Q.1 Three infinitely long conductors R, S and T are lying in a horizontal plane as shown in the figure. The currents in the respective conductors are



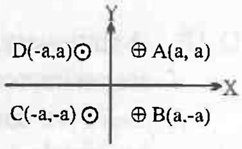
$$I_R = I_0 \sin(\omega t + \frac{2\pi}{3})$$

$$I_S = I_0 \sin(\omega t)$$

$$I_T = I_0 \sin(\omega t - \frac{2\pi}{3})$$

Find the amplitude of the vertical component of the magnetic field at a point P, distance 'a' away from the central conductor S.

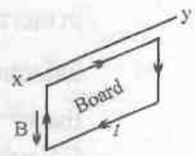
Q.2 Four long wires each carrying current I as shown in the figure are placed at the points A, B, C and D. Find the magnitude and direction of



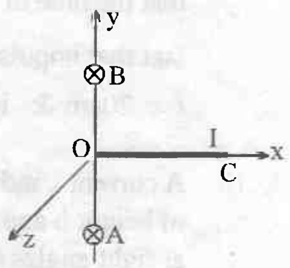
(i) magnetic field at the centre of the square.
(ii) force per metre acting on wire at point D.

Q.3 An infinite wire, placed along z-axis, has current I_1 in positive z-direction. A conducting rod placed in xy plane parallel to y-axis has current I_2 in positive y-direction. The ends of the rod subtend + 30° and – 60° at the origin with positive x-direction. The rod is at a distance a from the origin. Find net force on the rod.

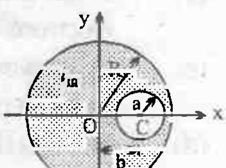
Q.4 A square cardboard of side l and mass m is suspended from a horizontal axis XY as shown in figure. A single wire is wound along the periphery of board and carrying a clockwise current I. At t = 0, a vertical downward magnetic field of induction B is switched on. Find the minimum value of B so that the board will be able to rotate up to horizontal level.



Q.5 A straight segment OC (of length L meter) of a circuit carrying a current I amp is placed along the x-axis. Two infinitely ling straight wires A and B ,each extending form z = – ∞ to + ∞, are fixed at y = – a metre and y = +a metre respectively, as shown in the figure. If the wires A and B each carry a current I amp into plane of the paper. Obtain the expression for the force acting on the segment OC. What will be the force OC if current in the wire B is reversed?

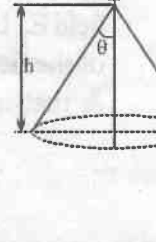


Q.6 A very long straight conductor has a circular cross-section of radius R and carries a current density J. Inside the conductor there is a cylindrical hole of radius a whose axis is parallel to the axis of the conductor and a distance b from it. Let the z-axis be the axis of the conductor, and let the axis of the hole be at x = b. Find the magnetic field

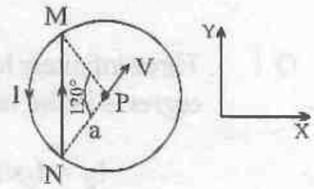


(a) on the x = axis at x = 2R
(b) on the y = axis at y = 2R.

Q.7 Q charge is uniformly distributed over the same surface of a right circular cone of semi-vertical angle θ and height h. The cone is uniformly rotated about its axis at angular velocity ω. Calculated associated magnetic dipole moment.



Q.8 A wire loop carrying current I is placed in the X-Y plane as shown in the figure

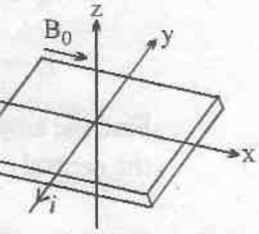


(a) If a particle with charge +Q and mass m is placed at the centre P and given a velocity along NP (fig). Find its instantaneous acceleration

(b) If an external uniform magnetic induction field $\vec{B} = B\hat{i}$ is applied, find the torque acting on the loop due to the field.

Q.9 A long straight wire carries a current of 10 A directed along the negative y-axis as shown in figure. A uniform magnetic field B_0 of magnitude 10^{-6} T is directed parallel to the x-axis. What is the resultant magnetic field at the following points?

(a) $x = 0,\ z - 2$ m; (b) $x = 2$ m, $z = 0$; (c) $x = 0$, $z = -0.5$ m

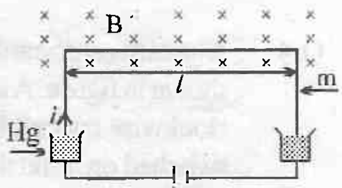


Q.10 A stationary, circular wall clock has a face with a radius of 15cm. Six turns of wire are wound around its perimeter, the wire carries a current 2.0 A in the clockwise direction. The clock is located, where there is a constant, uniform external magnetic field of 70 mT (but the clock still keeps perfect time) at exactly 1:00 pm, the hour hand of the clock points in the direction of the external magnetic field

(a) After how many minutes will the minute hand point in the direction of the torque on the winding due to the magnetic field ?

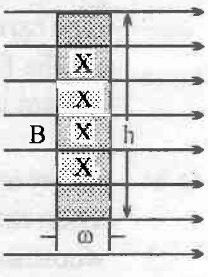
(b) What is the magnitude of this torque.

Q.11 A U-shaped wire of mass m and length l is immersed with its two ends in mercury (see figure). The wire is in a homogeneous field of magnetic induction **B**. If a charge, that is, a current pulse $q = \int i\,dt$, is sent through the wire, the wire will jump up.



Calculate, from the height h that the wire reaches, the size of the charge or current pulse, assuming that the time of the current pulse is very small in comparision with the time of flight. Make use of the fact that impulse of force equals $\int F\,dt$, which equals mv. Evaluate q for B = 0.1 Wb/m^2, m = 10gm, ℓ = 20cm & h = 3 meters.[g = 10 m/s^2]

Q.12 A current i, indicated by the crosses in fig. is established in a strip of copper of height h and width w. A uniform field of magnetic induction **B** is applied at right angles to the strip.



(a) Calculate the drift speed v_d for the electrons.

(b) What are the magnitude and dirction of the magnetic force **F** acting on the electrons?

(c) What would the magnitude & direction of homogeneous electric field **E** have to be in order to counter balance the effect of the magnetic field ?

(d) What is the voltage V necessary between two sides of the conductor in order to create this field E? Between which sides of the conductor would this voltage have to be applied ?

(e) If no electric field is applied form the outside the electrons will be pushed somewhat to one side & thereforce will give rise to a uniform electric field E_H across the conductor untill the force of this electrostatic field E_H balanace the magnetic forces encountered in part (b) . What will be the magnitude and direction of the field $\mathbf{E_H}$? Assume that n, the number of conduction electrons per unit volume, is 1.1×10^{29}/m^3 & that h = 0.02 meter , w = 0.1cm , i = 50 amp , & B = 2 webers/meter^2.

Q.13(a) A rigid circular loop of radius r & mass m lies in the xy plane on a flat table and has a current I flowing in it. At this particular place, the earth's magnetic field is $\vec{B} = \vec{B}_x\,\hat{i} + \vec{B}_y\,\hat{j}$. How large must I be before one edge of the loop will lift from table ?

(b) Repeat if, $\vec{B} = \vec{B}_x\,\hat{i} + \vec{B}_z\,\hat{k}$.

Q.14 Zeeman effect . In Bohr's theory of the hydrogen atom the electron can be thought of as moving in a circular orbit of radius r about the proton . Suppose that such an atom is placed in a magnetic field, with the plane of the orbit at right angle to B.

(a) If the electron is circulating clockwise, as viewed by an observer sighting along B, will the angular frequency increase or decrease?

(b) What if the electron is circulating counterclockwise? Assume that the orbit radius does not change.

Q.15 In above problem show that the change in frequency of rotation caused by the magnete field is given approximately by $\Delta v = \pm \frac{Be}{4\pi m}$. Such frequency shifts were actually observed by Zeeman in 1896.

Q.16 A square loop of wire of edge *a* carries a current *i* .

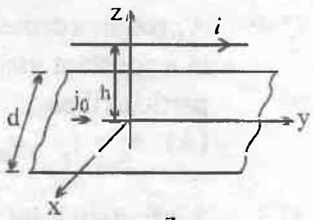
(a) Show that B for a point on the axis of the loop and a distance *x* from its centre is given by,

$$B = \frac{4\mu_0 i a^2}{\pi\left(4x^2 + a^2\right)\left(4x^2 + 2a^2\right)^{1/2}}$$

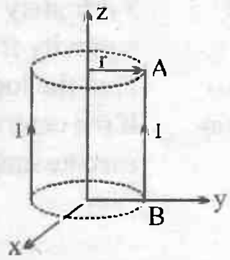
(b) Can the result of the above problem be reduced to give field at $x = 0$?

(c) Does the square loop behave like a dipole for points such that $x >> a$? If so, what is its dipole moment?

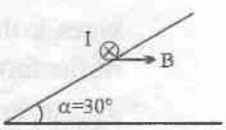
Q.17 A conductor carrying a current i is placed parallel to a current per unit width j_0 and width d, as shown in the figure. Find the force per unit lenght on the coductor.



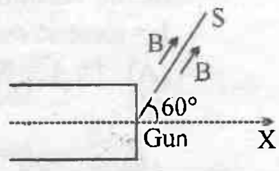
Q.18 Find the work and power required to move the conductor of length *l* shown in the fig. one full turn in the anticlockwise direction at a rotational frequency of n revolutions per second if the magnetic field is of magnitude B_0 everywhere and points radially outwards from Z-axis. The figure shows the surface traced by the wire AB.



Q.19 The figure shows a conductor of weight 1.0 N and length L = 0.5 m placed on a rough inclined plane making an angle 30^0 with the horizontal so that conductor is perpendicular to a uniform horizontal magnetic field of induction B = 0.10 T. The coefficient of static friction between the conductor and the plane is 0.1. A current of I = 10 A flows through the conductor inside the plane of this paper as shown. What is the force needed to be the applied parallel to the inclined plane to sustaining the conductor at rest?



Q.20 An electron gun G emits electron of energy 2kev traveling in the (+)ve x-direction. The electron are required to hit the spot S where GS = 0.1m & the line GS makes an angle of 60° with the x-axis, as shown in the fig. A uniform magnetic field B parallel to GS exists in the region outsiees to electron gun. Find the minimum value of B needed to make the electron hit S .

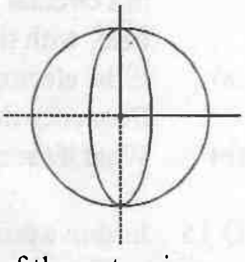


EXERCISE # III

Q.1 A battery is connected between two points A and B the circumference of a uniform conducting ring of radius r and resistance R. One of the arcs AB of the ring subtends an angle θ at the centre. The value of the magnetic induction at the centre due to the current in the ring is : [JEE '95, 2]

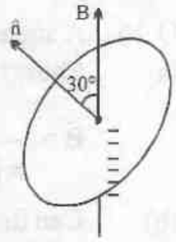
(A) zero, only if $\theta = 180°$
(B) zero for all values of θ
(C) proportional to $2(180° - \theta)$
(D) inversely proportional to r

Q.2 Two insulated rings, one slightly smaller diameter than the other, are suspended along their diameter as shown, initially the planes of the rings are mutually perpendicular when a steady current is set up in each of them : [IIT '95, 1]



(A) The two rings rotate to come into a common plane
(B) The inner ring oscillates about its initially position
(C) The outer ring stays stationary while the inner one moves into the plane of the outer ring
(D) The inner ring stays stationary while the outer one moves into the plane of the inner ring

Q.3 An electron in the ground state of hydrogen atom is revolving in anticlock-wise direction in a circular orbit of radius R.



(i) Obtain an expression for the orbital magnetic dipole moment of the electron

(ii) The atom is placed in a uniform magnetic. Induction $\bar{B}$ such that the plane normal of the electron orbit makes an angle of 30^0 with the magnetic induction. Find the torque experienced by the orbiting electron. [JEE '96, 5]

Q.4 A proton, a deuteron and an α-particle having the same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_p, r_d & r_α denote respectively the radii of the trajectories of these particles then : [JEE '97, 1]

(A) $r_\alpha = r_p < r_d$ (B) $r_\alpha > r_d > r_p$ (C) $r_\alpha = r_d > r_p$ (D) $r_p = r_d = r_\alpha$

Q.5 3 infinitely long thin wires each carrying current *i* in the same direction, are in the x-y plane of a gravity free space. The central wire is along the y-axis while the other two are along $x = \pm d$.

(i) Find the locus of the points for which the magnetic field B is zero.

(ii) If the central wire is displaced along the z-direction by a small amount & released, show that it will execute simple harmonic motion. If the linear density of the wires is λ, find the frequency of oscillation. [JEE '97, 5]

Q.6 Select the correct alternative(s). [JEE '98, 2 + 2 + 2]

(i) Two very long, straight, parallel wires carry steady currents I & – I respectively. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires, in the plane of the wires. Its instantaneous velocity $\vec{v}$ is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is :

(A) $\frac{\mu_0 Iqv}{2\pi d}$ (B) $\frac{\mu_0 Iqv}{\pi d}$ (C) $\frac{2\mu_0 Iqv}{\pi d}$ (D) 0

(ii) Let $[\in_0]$ denote the dimensional formula of the permittivity of the vaccum and $[\mu_0]$ that of the permeability of the vacuum. If M = mass, L = length, T = time and I = electric current,

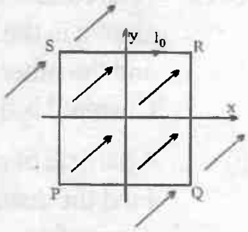
(A) $[\in_0] = M^{-1} L^{-3} T^2 I$ (B) $[\in_0] = M^{-1} L^{-3} T^4 I^2$ (C) $[\mu_0] = MLT^{-2} I^{-2}$ (D) $[\mu_0] = ML^2 T^{-1} I$

(iii) Two particles, each of mass m & charge q, are attached to the two ends of a light rigid rod of length $2R$. The rod is rotated at constant angular speed about a perpendicular axis passing through its centre. The ratio of the magnitudes of the magnetic moment of the system & its angular momentum about the centre of the rod is :

(A) $\frac{q}{2m}$ (B) $\frac{q}{m}$ (C) $\frac{2q}{m}$ (D) $\frac{q}{\pi m}$

Q.7 A particle of mass m & charge q is moving in a region where uniform, constant electric and magnetic fields $\vec{E}$ & $\vec{B}$ are present, $\vec{E}$ & $\vec{B}$ are parallel to each other. At time t = 0 the velocity $\vec{v}_0$ of the particle is perpendicular to $\vec{E}$. (assume that its speed is always << c, the speed of light in vacuum). Find the velocity $\vec{v}$ of the particle at time t. You must express your answer in terms of t, q, m, the vectors $\vec{v}_0$, $\vec{E}$ & $\vec{B}$ and their magnitudes v_0, E & B. [JEE '98, 8]

Q.8 A uniform, constant magnetic field $\vec{B}$ is directed at an angle of 45° to the x-axis in the xy-plane, PQRS is a rigid square wire frame carrying a steady current I_0(clockwise), with its centre at the origin O. At time t = 0, the frame is at rest in the position shown in the figure, with its sides parallel to the x & y axes. Each side of the frame is of mass M & length L.



(a) What is the torque $\vec{\tau}$ about O acting on the frame due to the magnetic field ?

(b) Find the angle by which the frame rotates under the action of this torque in a short interval of time Δt, & the axis about which this rotation occurs (Δt is so short that any variation in the torque during this interval may be neglected) Given the moment of inertia of the frame about an axis through its centre perpendicular to its plane is $4/3\ ML^2$. [JEE '98, 2 + 6]

Q 9 A charged particle is released from rest in a region of steady and uniform electric and magnetic fields which are parallel to each other. The particle will move in a

(A) straight line (B) circle (C) helix (D) cycloid [JEE'99, 2]

Q.10 The region between x = 0 and x = L is filled with uniform, steady magnetic field $B_0\hat{k}$. A particle of mass *m*, positive charge q and velocity $v_0\hat{i}$ travels along x-axis and enters the region of the magnetic field. Neglect the gravity throughout the question.

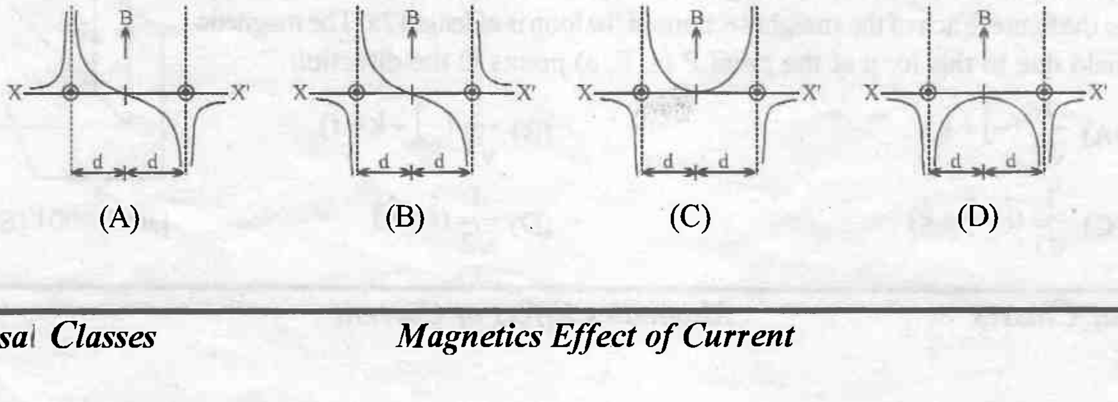
(a) Find the value of L if the particle emerges from the region of magnetic field with its final velocity at an angle 30° to its initial velocity.

(b) Find the final velocity of the particle and the time spent by it in the magnetic field, if the magnetic field now extends upto 2.1L. [JEE '99, 6 + 4]

Q.11 (i) A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on

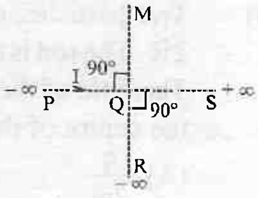
(A) ω and q (B) ω, q and m (C) q and m (D) ω and m

(ii) Two long parallel wires are at a distance 2d apart. They carry steady equal currents flowing out of the plane of the paper, as shown. The variation of the magnetic field B along the XX' is given by



(A) (B) (C) (D)

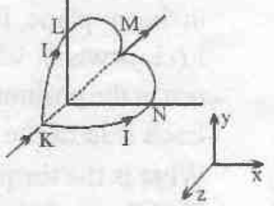
(iii) An infinitely long conductor PQR is bent to form a right angle as shown. A current I flows through PQR. The magnetic field due to this current at the point M is H_1. Now, another infinitely long straight conductor QS is connected at Q so that the current in PQ remaining unchanged. The magnetic field at M is now H_2. The ratio H_1/H_2 is given by



(A) 1/2 (B) 1 (C) 2/3 (D) 2

(iv) An ionized gas contains both positive and negative ions. If it is subjected simultaneously to an electric field along the +x direction and a magnetic field along the +z direction, then
(A) positive ions deflect towards +y direction and negative ions towards –y direction
(B) all ions deflect towards +y direction.
(C) all ions deflect towards –y direction
(D) positive ions deflect towards –y direction and negative ions towards +y direction. [JEE 2000 (Scr)]

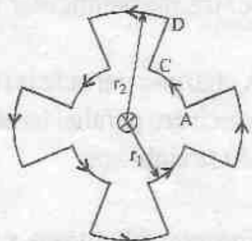
Q.12 A circular loop of radius R is bent along a diameter and given a shape as shown in the figure. One of the semicircles (KNM) lies in the x – z plane and the other one (KLM) in the y – z plane with their centers at the origin. Current I is flowing through each of the semicircles as shown in figure.



(i) A particle of charge q is released at the origin with a velocity $v = -v_0 \hat{i}$. Find the instantaneous force f on the particle. Assume that space is gravity free.

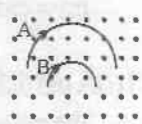
(ii) If an external uniform magnetic field $B \hat{j}$ is applied, determine the forces F_1 and F_2 on the semicircles KLM and KNM due to this field and the net force F on the loop. [JEE 2000 Mains, 4 + 6]

Q.13 A current of 10A flows around a closed path in a circuit which is in the horizontal plane as shown in the figure. The circuit consists of eight alternating arcs of radii $r_1 = 0.08$ m and $r_2 = 0.12$ m. Each arc subtends the same angle at the centre.



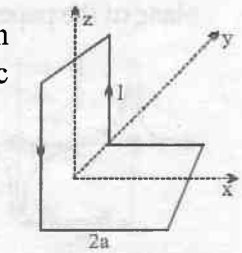
(a) Find the magnetic field produced by this circuit at the centre.
(b) An infinitely long straight wire carrying a current of 10A is passing through the centre of the above circuit vertically with the direction of the current being into the plane of the circuit. What is the force acting on the wire at the centre due to the current in the circuit? What is the force acting on the arc AC and the straight segment CD due to the current at the centre? [JEE 2001, 5 + 5]

Q.14 Two particles A and B of masses m_A and m_B respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are v_A and v_B respectively and the trajectories are as shown in the figure. Then



(A) $m_A v_A < m_B v_B$ (B) $m_A v_A > m_B v_B$
(C) $m_A < m_B$ and $v_A < v_B$ (D) $m_A = m_B$ and $v_A = v_B$ [JEE, 2001 (Scr)]

Q.15 A non-planar loop of conducting wire carrying a current I is placed as shown in the figure. Each of the straight sections of the loop is of length 2a. The magnetic field due to this loop at the point P (a, 0, a) points in the direction



(A) $\frac{1}{\sqrt{2}}(-\hat{j}+\hat{k})$ (B) $\frac{1}{\sqrt{3}}(-\hat{j}+\hat{k}+\hat{i})$

(C) $\frac{1}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})$ (D) $\frac{1}{\sqrt{2}}(\hat{i}+\hat{k})$ [JEE, 2001 (Scr)]

Q.16 A coil having N turns is wound tightly in the form of a spiral with inner and outer radii a and b respectively. When a current I passes through the coil, the magnetic field at the centre is [JEE, 2001 Screening]

(A) $\frac{\mu_0 NI}{b}$ (B) $\frac{2\mu_0 NI}{a}$ (C) $\frac{\mu_0 NI}{2(b-a)} ln\frac{b}{a}$ (D) $\frac{\mu_0 I^N}{2(b-a)} ln\frac{b}{a}$

Q.17 A particle of mass m and charge q moves with a constant velocity v along the positive x direction. It enters a region containing a uniform magnetic field B directed along the negative z direction, extending from x = a to x = b. The minimum value of v required so that the particle can just enter the region x > b is

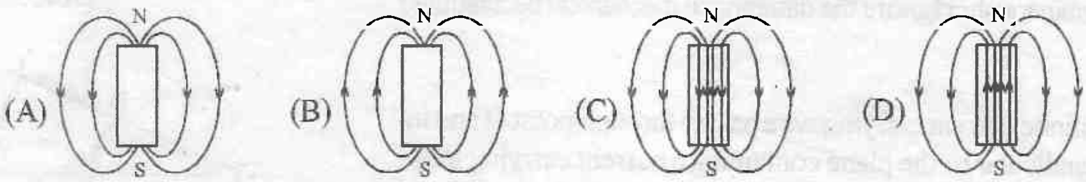
(A) q b B/m (B) q(b – a) B/m (C) q a B/m (D) q(b + a) B/2m

[JEE 2002 (screening), 3]

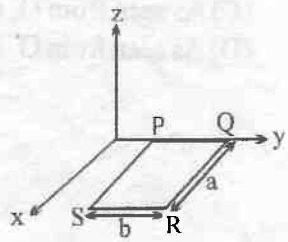
Q.18 A long straight wire along the z-axis carries a current I in the negative z direction. The magnetic vector field $\vec{B}$ at a point having coordinates (x, y) in the z = 0 plane is [JEE 2002 (screening), 3]

(A) $\frac{\mu_0 I}{2\pi}\frac{(y\hat{i} - x\hat{j})}{(x^2+y^2)}$ (B) $\frac{\mu_0 I}{2\pi}\frac{(x\hat{i} + y\hat{j})}{(x^2+y^2)}$ (C) $\frac{\mu_0 I}{2\pi}\frac{(x\hat{j} - y\hat{i})}{(x^2+y^2)}$ (D) $\frac{\mu_0 I}{2\pi}\frac{(x\hat{i} - y\hat{j})}{(x^2+y^2)}$

Q.19 The magnetic field lines due to a bar magnet are correctly shown in [JEE 2002 (screening), 3]



Q.20 A rectangular loop PQRS made from a uniform wire has length a, width b and mass m. It is free to rotate about the arm PQ, which remains hinged along a horizontal line taken as the y-axis (see figure). Take the vertically upward direction as the z-axis. A uniform magnetic field $\vec{B} = (3\hat{i} + 4\hat{k}) B_0$ exists in the region. The loop is held in the x-y plane and a current I is passed through it. The loop is now released and is found to stay in the horizontal position in equilibrium.

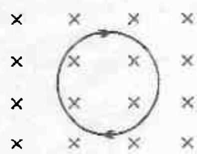


(a) What is the direction of the current I in PQ?

(b) Find the magnetic force on the arm RS.

(c) Find the expression for I in terms of B_0, a, b and m. [JEE 2002, 1+1+3]

Q.21 A circular coil carrying current I is placed in a region of uniform magnetic field acting perpendicular to a coil as shown in the figure. Mark correct option [JEE 2003 (Scr)]



(A) coil expands (B) coil contracts

(C) coil moves left (D) coil moves right

Q.22

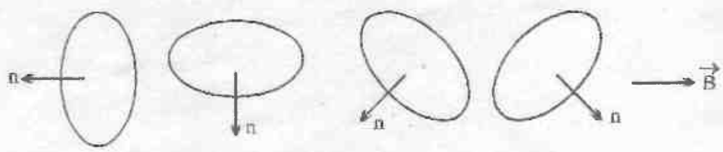
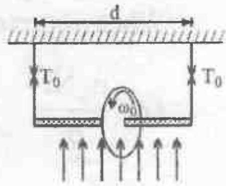


Figure represents four positions of a current carrying coil is a magnetic field directed towards right. $\hat{n}$ represent the direction of area of vector of the coil. The correct order of potential energy is : [JEE 2003 (Scr)]

(A) I > III > II > IV (B) I < III < II < IV

(C) IV < I < II < II (D) II > II > IV > I

Q.23 A wheel of radius R having charge Q, uniformly distributed on the rim of the wheel is free to rotate about a light horizontal rod. The rod is suspended by light inextensible stringe and a magnetic field B is applied as shown in the figure. The initial tensions in the strings are T_0. If the breaking tension of the strings are $\frac{3T_0}{2}$, find the maximum angular velocity ω_0 with which the wheel can be rotate. [JEE 2003]



Q.24 A proton and an alpha particle, after being accelerated through same potential difference, enter a uniform magnetic field the direction of which is perpendicular to their velocities. Find the ratio of radii of the circular paths of the two particles. [JEE 2004]

Q.25 In a moving coil galvanometer, torque on the coil can be expressed as $\tau = ki$, where i is current through the wire and k is constant. The rectangular coil of the galvanometer having numbers of turns N, area A and moment of inertia I is placed in magnetic field B. Find

(a) k in terms of given parameters N, I, A and B.

(b) the torsional constant of the spring, if a current i_0 produces a deflection of $\pi/2$ in the coil in reaching equilibrium position.

(c) the maximum angle through which coil is deflected, id charge Q is passed through the coil almost instantaneously. (Ignore the damping in mechanical oscillations) [JEE 2005]

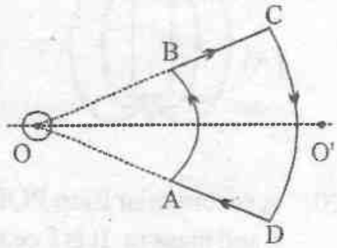
Q.26 An infinite current carrying wire passes through point O and in perpendicular to the plane containing a current carrying loop ABCD as shown in the figure. Choose the correct option (s).

(A) Net force on the loop is zero.

(B) Net torque on the loop is zero.

(C) As seen from O, the loop rotates clockwise.

(D) As seen from O, the loop rotates anticlockwise [JEE 2006]



ANSWER KEY

EXERCISE # I

Q.1 $\frac{\sqrt{2}\,\mu_0 i}{8\pi l}$

Q.2 $\frac{\sqrt{5}}{2\sqrt{2}} 4\pi \times 10^{-5}$ T

Q.3 $\frac{(2\sqrt{2}-1)\mu_0 i}{\pi a}$

Q.4 zero

Q.5 $\frac{\mu_0 I}{4R}\left(\frac{3}{4}\hat{k}+\frac{1}{\pi}\hat{i}\right)$

Q.6 $\frac{\mu_0 i}{4\pi r}\left[\frac{3}{2}\pi+1\right]$

Q.7 $B = \frac{\mu_0 i}{4\pi R}\sqrt{2\left(2\pi^2 - 2\pi + 1\right)}$

Q.8 (i) 1.3×10^{-4}T, (ii) zero

Q.9 μ_0 weber.m^{-1}

Q.10 $\frac{\mu_0 iqv}{2\pi a}$

Q.11 $10\hat{k}$

Q.12 $\frac{2mv_C}{qB}$

Q.13 zero

Q.14 $F = \alpha a^2 i\,\hat{j}$

Q.15 $i_1 = 0.1110$ A, $i_2 = 0.096$ A

Q.16 $4/\sqrt{7}$

Q.17 (a) $\frac{3mv^2}{4qa}$, (b) $\frac{3mv^3}{4a}$, (c) zero

Q.18 In the plane of the drawing from right to left

Q.19 $B_1 = \frac{\mu_0 b r_1^2}{3}$, $B_2 = \frac{\mu_0 b R^3}{3r_2}$

Q.20 $T = 2\pi\sqrt{\frac{m}{6IB}} = 0.57$ s

Q.21 $t = m\frac{\alpha}{qB}$, where $\alpha = \sin^{-1}\left(\frac{dB\sqrt{q}}{\sqrt{2mV}}\right)$

Q.22 $\frac{mEI}{Be}$

Q.23 $\frac{\mu_0 I I' C}{2\pi}\left[\frac{1}{a}-\frac{1}{b}\right]$ to the left

Q.24 $\sqrt{2}$ IRB

Q.25 $\frac{W}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi}\ln\frac{r_2}{r_1} = 27.6\ \mu$J/m

EXERCISE # II

Q.1 $\frac{\mu_0 I_0}{2\pi}\frac{\sqrt{3}\,b}{(a^2+b^2)}$

Q.2 (i) $\frac{\mu_0}{4\pi}\left(\frac{4I}{a}\right)$ along Y-axis,

(ii) $\frac{\mu_0}{4\pi}\left(\frac{I^2}{2a}\right)\sqrt{10}$, $\tan^{-1}\left(\frac{1}{3}\right)+\pi$ with positive axis

Q.3 $\frac{\mu_0 I_1 I_2}{4\pi} \ln(3)$ along – ve z direction Q.4 $\frac{mg}{2Il}$

Q.5 $F = \left(\frac{\mu_0 I^2}{2\pi}\right) \ell n\left(\frac{L^2 + a^2}{a^2}\right)(-\hat{k})$, zero

Q.6 (a) $B = \frac{\mu_0 J}{2}\left(\frac{a^2}{2R-b} - \frac{R}{2}\right)$, (b) $B_x = \mu_0 J R\left(\frac{1}{4} - \frac{a^2}{4R^2 + b^2}\right)$, $B_y = -\frac{\mu_0 J}{2}\left(\frac{a^2 b}{4R^2 + b^2}\right)$

Q.7 $\frac{Q_\omega}{4} h^2 \tan^2\theta$ Q.8 (a) $\frac{QV}{m}\frac{\mu_0 I}{6a}\left(\frac{3\sqrt{3}}{\pi} - 1\right)$, (b) $\vec{\tau} = BI\left(\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right)a^2 \hat{j}$

Q.9 **(a)** 0 **(b)** 1.41×10^{-6} T, 45° in xz-plane, **(c)** 5×10^{-6} T, +x-direction]

Q.10 **(a)** 20 min. **(b)** 5.94×10^{-2} Nm

Q.11 $\sqrt{15}$ C

Q.12 **(a)** 1.4×10^{-4} m/s **(b)** 4.5×10^{-23} N (down) **(c)** 2.8×10^{-4} V/m (down)
(d) 5.7×10^{-6} V (top +, bottom –) **(e)** same as (c)

Q.13 **(a)** $I = \frac{mg}{\pi r\left(B_x^2 + B_y^2\right)^{1/2}}$ **(b)** $I = \frac{mg}{\pi r B_v}$ Q.14 **(a)** increase, **(b)** decrease

Q.17 $\frac{\mu_0 i I_0}{\pi}\tan^{-1}\left(\frac{d}{2h}\right)(-\hat{k})$ Q.18 $-2\pi r B_0 i l$, $-2\pi r B_0 i l n$

Q.19 0.62 N < F < 0.88 N Q.20 $B_{min} = 4.7 \times 10^{-3}$ T

EXERCISE # III

Q.1 B Q.2 A Q.3 (i) $m = \frac{eh}{4\pi m}$; $|\vec{\tau}| = \frac{ehB}{8\pi m}$ Q.4 A

Q.5 $z = 0, x = \pm\frac{d}{\sqrt{3}}$, (ii) $\frac{I}{2\pi d}\sqrt{\frac{\mu_0}{\pi\lambda}}$ Q.6 (i) D (ii) B, C (iii) A

Q.7 $\vec{v} = \frac{q}{m}\vec{E}t + \vec{v}_0 \cos\omega t + [v_0 \sin\omega t]\hat{k}$, where $\omega = \frac{qB}{m}$; $\hat{k} = (\vec{v}_0 \times \vec{E})/|\vec{v}_0 \times \vec{E}|$

Q.8 (a) $\vec{\tau} = \frac{BI_0L^2}{\sqrt{2}}(\hat{i} - \hat{j})$ (b) $\theta = \frac{3}{4}\frac{BI_0}{M}\Delta t^2$ Q.9 A

Q.10 (a) $\frac{mv_0}{2qB_0}$ (b)velocity=-v, time= $\frac{\pi m}{qB_0}$ Q.11 (i) C (ii) B (iii) C (iv) C

Q.12 (i) $-\frac{\mu_0 I}{4R} q v_0 \hat{k}$ (ii) $F_1 = 2IRB$ $F_2 = 2IRB$, Net force $= F_1 + F_2 = 4IRB\ \hat{i}$

Q.13 (a) 6.6×10^{-5}T, (b) 0, 0, 8×10^{-6}Nt

Q.14 B Q.15 D Q.16 C Q.17 B Q.18 A Q.19 D

Q.20 (a) current in loop PQRS is clockwise from P to QRS., (b) $\vec{F} = BI_0 b\ (3\hat{k}-4\hat{i})$, (c) $I = \frac{mg}{6bB_0}$

Q.21 A Q.22 A Q.23 $\omega = \frac{dT_0}{QR^2B}$ Q.24 $\frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{m_\alpha}\cdot\frac{q_\alpha}{q_p}} = \frac{1}{\sqrt{2}}$

Q.25 (a) k = NAB, (b) $C = \frac{2i_0 NAB}{\pi}$, (c) $Q \times \sqrt{\frac{NAB\pi}{2i_0}}$ Q.26 A,C

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

MAGNETIC EFFECT OF CURRENT

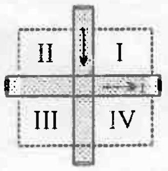
QUESTION FOR SHORT ANSWER

Q.1 Consider a magnetic field line. Is the magnitude of $\vec{B}$ constant or variable along such a line? Can you give an example of each case?

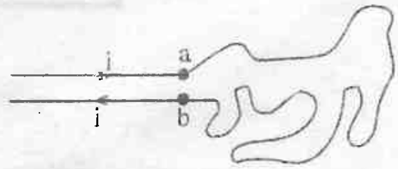
Q.2 A current is sent through a vertical spring from whose lower end a weight is hanging. What will happen?

Q.3 $B = \mu_0 i / 2\pi d$ suggets that a strong magnetic field is set up at points near a long wire carrying a current. Since there is a current i and magnetic field $\vec{B}$, why is there not a force on the wire in accord with the equation $\vec{F}_B = i\vec{L} \times \vec{B}$?

Q.4 Two fixed wires cross each other perpendicularly so that they do not actually touch but are close to each other, as shown in figure. Equal currents i exist in each wire in the directions indicated. In what region(s) will there be some points of zero net magnetic field?

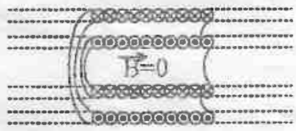


Q.5 A messy loop of limp wire is placed on a frictionless table and anchored at points a and b as shown in figure. If a current i is now passed through the wire, will it try to form a circular loop or will it try to bunch up further?



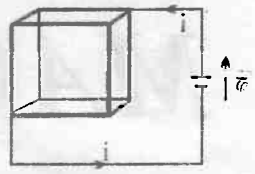
Q.6 A very long conductor has a square cross section and contains a coaxial cavity also with a square cross section. Current is distributed uniformly over the material cross section of the conductor. Is the magnetic field in the cavity equal to zero? Justify you answer.

Q.7 Two long solenoids are nested on the same axis, as in figure. They carry identical currents but in opposite directions. If there is no magnetic field inside the inner solenoid, what can you say about n, the number of turns per unit length, for the two solenoids? Which one, if either, has the larger value?



Q.8 The magnetic field at the center of a circular current loop has the value $B = \mu_0 i / 2R$. However, the electric field at the center of a ring of charge is zero. Why this difference?

Q.9 A steady current is set up in a cubical network of resistive wires, as in figure. Use symmetry arguments to show that the magnetic field at the center of the cube is zero



Q.10 A copper pipe filled with an electrolyte. When a voltage is applied, the current in the electrolyte is constituted by the movement of positive and negative ions in opposite directions. Will such a pipe experience a force when placed in a magnetic field perpendicular to the current.

Q.11 Magnetic moments arise due to charges. Can a system have magnetic moments even though it has no charge.

Q.12 Imagine that the room in which you are seated is fillled with a uniform magnetic field with B pointing vertically upward. A circular loop of wire has its plane horizontal. For what direction of current in the loop, as viewed from above, will the loop be in stable eqiulibrium with respect to forces & torques of magnetic origin ?

Q.13 Two current-carrying wires may attract each other. In absence of other forces, the wires will move towards each other increasing the kinetic energy. From where does this energy come?

Q.14 In order to have a current in a long wire, it should be connected to a battery or some such device. Can we obtain the magnetic field due to a straight, long wire by using Ampere's law without mentioning this other part of the circuit.

Q.15 A uniform magnetic field fills a certian cubical region of space. Can an electron be fired into this cube from the outside in such a way that it will travel in a closed circular path inside the cube?

Q.16 In Ampere's law $\oint \vec{B}.\vec{dl} = \mu_0 i$ the current outside the curve is not included on the right hand side. Does it mean that the magnetic field B calculated by using Ampere's law, gives the contribution of only the currents crossing the area bounded by the curve ?

Q.17 A magnetic field that varies in magnitude form point to point, but has constant direction (East to West) is set up in a chamber . A charged particle enters the chamber and travels undeflected along a straight path with constant speed . What can you say about the initial velocity of the particle?

Q.18 A charged particle enters an environment of a strong & non-uniform magnetic field varying from point to point both in magnitude and direction and comes out of it following a complicated trajectory. Would its final speed equal the initial speed , if it suffered no collisions with the environment.

Q.19 A straight wire carrying on electric current is placed along the axis of a uniformly charged ring. Will there be a magnetic force on the wire if the ring starts rotating about the wire ? If yes, in which direction ?

Q.20 An electron travelling West to East enters a chamber having a uniform electrostatic field in North to South direction . Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight line path .

Q.21 The magnetic field inside a tightly wound, long solenoid is $B = \mu_0 ni$. It suggests that the field does not depend on the total length of the solenoid, and hence if we add more loops at the ends of a solenoid the field should not increase. Explain qualitatively why the extra-added loops do not have a considerable effect on the field inside the solenoid.

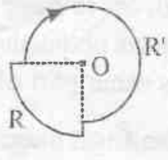
Q.22 A lightening conductor is connected to the earth by a circular copper pipe. After lightning strikes, it is discovered that the pipe has turned into a circular rod. Explain the cause of this phenomenon.

Q.23 We know that the work required to turn a current loop end for end in an external magnetic field is $2\mu B$. Does this hold no matter what the original orientaion of the loop was ?

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

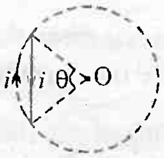
Q.1 A current of i ampere is flowing through each of the bent wires as shown the magnitude and direction of magnetic field at 0 is



(A) $\frac{\mu_0 i}{4}\left(\frac{1}{R}+\frac{2}{R'}\right)$ (B) $\frac{\mu_0 i}{4}\left(\frac{1}{R}+\frac{3}{R'}\right)$

(C) $\frac{\mu_0 i}{8}\left(\frac{1}{R}+\frac{3}{2R'}\right)$ (D) $\frac{\mu_0 i}{8}\left(\frac{1}{R}+\frac{3}{R'}\right)$

Q.2 Net magnetic field at the centre of the circle O due to a current carrying loop as shown in figure is ($\theta < 180°$)



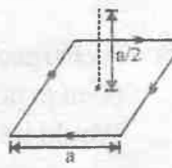
(A) zero

(B) perpendicular to paper inwards

(C) perpendicular to paper outwards

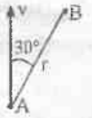
(D) is perpendicular to paper inwards if $\theta \le 90°$ and perpendicular to paper outwards if $90° \le \theta < 180°$

Q.3 The magnetic field due to a current carrying square loop of side a at a point located symmetrically at a distance of a/2 from its centre (as shown is)



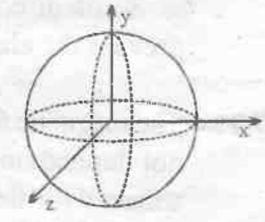
(A) $\frac{\sqrt{2}\,\mu_0 i}{\sqrt{3}\,\pi a}$ (B) $\frac{\mu_0 i}{\sqrt{6}\,\pi a}$ (C) $\frac{2\mu_0 i}{\sqrt{3}\,\pi a}$ (D) zero

Q.4 A charge particle A of charge q = 2 C has velocity v = 100 m/s. When it passes through point A and has velocity in the direction shown. The strength of magnetic field at point B due to this moving charge is (r = 2 m).



(A) 2.5 μT (B) 5.0 μT (C) 2.0 μT (D) None

Q.5 Three rings, each having equal radius R, are placed mutually perpendicular to each other and each having its centre at the origin of co-ordinate system. If current I is flowing thriugh each ring then the magnitude of the magnetic field at the common centre is



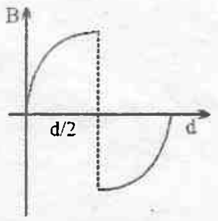
(A) $\sqrt{3}\frac{\mu_0 I}{2R}$ (B) zero (C) $(\sqrt{2}-1)\frac{\mu_0 I}{2R}$ (D) $(\sqrt{3}-\sqrt{2})\frac{\mu_0 I}{2R}$

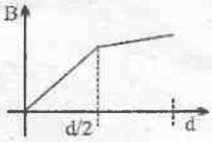
Q.6 Two concentric coils X and Y of radii 16 cm and 10 cm lie in the same vertical plane containing N-S direction. X has 20 turns and carries 16 A. Y has 25 turns & carries 18A. X has current in anticlockwise direction and Y has current in clockwise direction for an observer, looking at the coils facing the west. The magnitude of net magnetic field at their common centre is

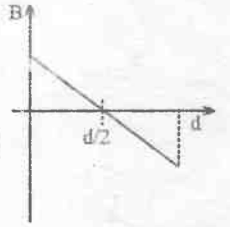
(A) $5\pi \times 10^{-4}$ T towards west (B) $13\pi \times 10^{-4}$ T towards east

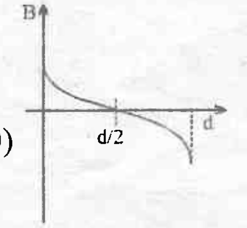
(C) $13\pi \times 10^{-4}$ T towards west (D) $5\pi \times 10^{-4}$ T towards east

Q.7 A uniform beam of positively charged particles is moving with a constant velocity parallel to another beam of negatively charged particles moving with the same velocity in opposite direction separated by a distance d. The variation of magnetic field B along a perpendicular line draw between the two beams is best represented by

(A) 

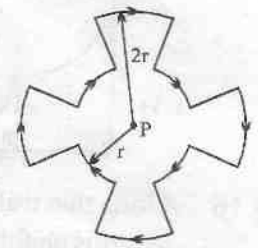
(B) 

(C) 

(D) 

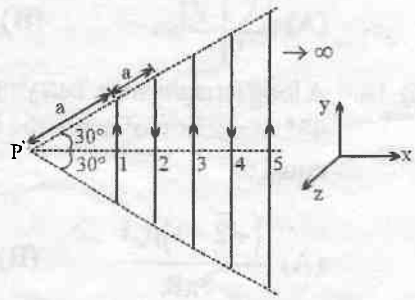
Q.8 The dimension of $\sqrt{\frac{\mu}{\in}}$ where μ is permeability & ε is permittivity is same as :
(A) Resistance (B) Inductance (C) Capacitance (D) None of these

Q.9 A current I flows around a closed path in the horizontal plane of the circle as shown in the figure. The path consists of eight arcs with alternating radii r and 2r. Each segment of arc subtends equal angle at the common centre P. The magnetic field produced by current path at point P is



(A) $\frac{3}{8}\frac{\mu_0 I}{r}$; perpendicular to the plane of the paper and directed inward.
(B) $\frac{3}{8}\frac{\mu_0 I}{r}$; perpendicular to the plane of the paper and directed outward.
(C) $\frac{1}{8}\frac{\mu_0 I}{r}$; perpendicular to the plane of the paper and directed inward.
(D) $\frac{1}{8}\frac{\mu_0 I}{r}$; perpendicular to the plane of the paper and directed outward..

Q.10 Infinite number of straight wires each carrying current I are equally placed as shown in the figure. Adjacent wires have current in opposite direction. Net magnetic field at point P is

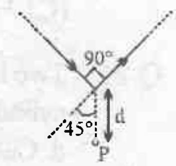


(A) $\frac{\mu_0 I}{4\pi}\frac{\ln 2}{\sqrt{3}\,a}\hat{k}$ (B) $\frac{\mu_0 I}{4\pi}\frac{\ln 4}{\sqrt{3}\,a}\hat{k}$
(C) $\frac{\mu_0 I}{4\pi}\frac{\ln 4}{\sqrt{3}\,a}(-\hat{k})$ (D) Zero

Q.11 A direct current is passing through a wire. It is bent to form a coil of one turn. Now it is further bent to form a coil of two turns but at smaller radius. The ratio of the magnetic induction at the centre of this coil and at the centre of the coil of one turn is
(A) 1 : 4 (B) 4 : 1 (C) 2 : 1 (D) 1 : 1

Q.12 Two mutually perpendicular conductors carrying currents I_1 and I_2 lie in one plane. Locus of the point at which the magnetic induction is zero, is a
(A) circle with centre as the point of intersection of the conductor.
(B) parabola with vertex as the point of intersection of the conductors
(C) straight line passing through the point of intersection of the conductors.
(D) rectangular hyperbola

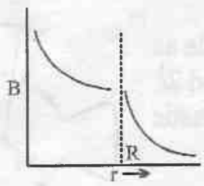
Q.13 Find the magnetic field at P due to the arrangement shown

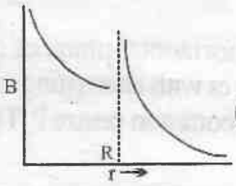


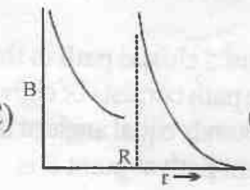
(A) $\frac{\mu_0 i}{\sqrt{2}\,\pi d}\left(1-\frac{1}{\sqrt{2}}\right)\otimes$ (B) $\frac{2\mu_0 i}{\sqrt{2}\,\pi d}\otimes$ (C) $\frac{\mu_0 i}{\sqrt{2}\,\pi d}\otimes$ (D) $\frac{\mu_0 i}{\sqrt{2}\,\pi d}\left(1+\frac{1}{\sqrt{2}}\right)\otimes$

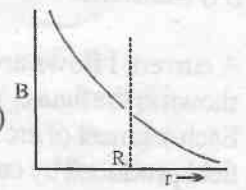
Q.14 Equal current i is flowing in three infinitely long wires along positive x, y and z directions. The magnitude field at a point (0, 0, –a) would be:
(A) $\frac{\mu_0 i}{2\pi a}(\hat{j}-\hat{i})$ (B) $\frac{\mu_0 i}{2\pi a}(\hat{i}+\hat{j})$ (C) $\frac{\mu_0 i}{2\pi a}(\hat{i}-\hat{j})$ (D) $\frac{\mu_0 i}{2\pi a}(\hat{i}+\hat{j}+\hat{k})$

Q.15 A thin, straight conductor lies along the axis of a hollow conductor of radius R. The two carry equal currents in the same direction. The magnetic field B is plotted against the distance r from the axis. Which of the following best represents the resulting curve?

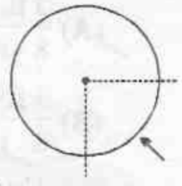
(A) 

(B) 

(C) 

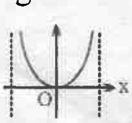
(D) 

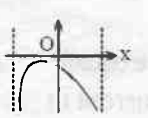
Q.16 A long thin walled pipe of radius R carries a current I along its length. The current density is uniform over the circumference of the pipe. The magnetic field at the center of the pipe due to quarter portion of the pipe shown, is

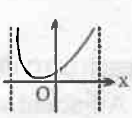


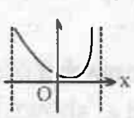
(A) $\frac{\mu_0 I\sqrt{2}}{4\pi^2 R}$ (B) $\frac{\mu_0 I}{\pi^2 R}$ (C) $\frac{2\mu_0 I\sqrt{2}}{\pi^2 R}$ (D) None

Q.17 Two very long straight parallel wires, parallel to y-axis, carry currents 4I and I, along +y direction and –y direction, respectively. The wires are passes through the x-axis at the points (d, 0, 0) and (– d, 0, 0) respectively. The graph of magnetic field z-component as one moves along the x-axis from x = – d to x = +d, is best given by

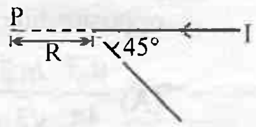
(A) 

(B) 

(C) 

(D) 

Q.18 A long straight wire, carrying current I, is bent at its midpoint to from an angle of 45°. Induction of magnetic field at point P, distant R from point of bending is equal to :



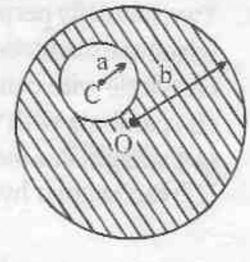
(A) $\frac{(\sqrt{2}-1)\mu_0 I}{4\pi R}$ (B) $\frac{(\sqrt{2}+1)\mu_0 I}{4\pi R}$ (C) $\frac{(\sqrt{2}-1)\mu_0 I}{4\sqrt{2}\pi R}$ (D) $\frac{(\sqrt{2}+1)\mu_0 I}{4\sqrt{2}\pi R}$

Q.19 A hollow cylinder having infinite length and carrying uniform current per unit length λ along the circumference as shown. Magnetic field inside the cylinder is



(A) $\frac{\mu_0\lambda}{2}$ (B) $\mu_0\lambda$ (C) $2\mu_0\lambda$ (D) none

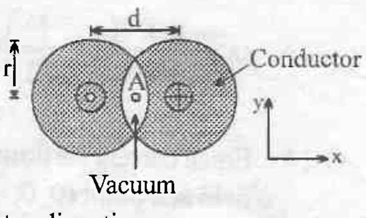
Q.20 A long straight metal rod has a very long hole of radius 'a' drilled parallel to the rod axis as shown in the figure. If the rod carries a current 'i' find the value of magnetic induction on the axis of the hole, where OC = c



(A) $\frac{\mu_0 ic}{\pi(b^2-a^2)}$ (B) $\frac{\mu_0 ic}{2\pi(b^2-a^2)}$

(C) $\frac{\mu_0 i(b^2-a^2)}{2\pi c}$ (D) $\frac{\mu_0 ic}{2\pi a^2 b^2}$

Q.21 Two long conductors are arranged as shown above to form overlapping cylinders, each of raidus r, whose centers are separated by a distance d. Current of density J flows into the plane of the page along the shaded part of one conductor and an equal current flows out of the plane of the page along the shaded portion of the other, as shown. What are the magnitude and direction of the magnetic field at point A?



(A) $(\mu_0/2\pi)\pi dJ$, in the +y-direction (B) $(\mu_0/2\pi)d^2/r$, in the +y-direction
(C) $(\mu_0/2\pi)4d^2J/r$, in the –y-direction (D) $(\mu_0/2\pi)Jr^2/d$, in the –y-direction
(E) There is no magnetic field at A.

Q.22 An electron is moving along positive x-axis. A uniform electric field exists towards negative y-axis. What should be the direction of magnetic field of suitable magnitude so that net force of electron is zero
(A) positive z- axis (B) negative z-axis (C) positive y-axis (D) negative y-axis

Q.23 A particle of charge q and mass m starts moving from the origin under the action of an electric field $\vec{E} = E_0\hat{i}$ and $\vec{B} = B_0\hat{i}$ with velocity $\vec{v} = v_0\hat{j}$. The speed of the particle will become $2v_0$ after a time
(A) $t = \frac{2mv_0}{qE}$ (B) $t = \frac{2Bq}{mv_0}$ (C) $t = \frac{\sqrt{3}\,Bq}{mv_0}$ (D) $t = \frac{\sqrt{3}\,mv_0}{qE}$

Q.24 An electron is projected with velocity v_0 in a uniform electric field E perpendicular to the field. Again it is projetced with velocity v_0 perpendicular to a uniform magnetic field B/ If r_1 is initial radius of curvature just after entering in the electric field and r_2 is initial radius of curvature just after entering in magnetic field then the ratio r_1/r_2 is equal to
(A) $\frac{Bv_0^2}{E}$ (B) $\frac{B}{E}$ (C) $\frac{Ev_0}{B}$ (D) $\frac{Bv_0}{E}$

Q.25 A uniform magnetic field $\vec{B} = B_0\hat{j}$ exists in a space. A particle of mass m and charge q is projected towards negative x-axis with speed v from the a point (d, 0, 0). The maximum value v for which the particle does not hit y-z plane is
(A) $\frac{2Bq}{dm}$ (B) $\frac{Bqd}{m}$ (C) $\frac{Bq}{2dm}$ (D) $\frac{Bqd}{2m}$

Q.26 Two protons move parallel to each other, keeping distance r between them, both moving with same velocity $\vec{V}$. Then the ratio of the electric and magnetic force of interaction between them is
(A) c^2/V^2 (B) $2c^2/V^2$ (C) $c^2/2V^2$ (D) None

Q.27 A charged particle of specific charge α is released from origin at time t = 0 with velocity $\vec{V} = V_o\hat{i} + V_o\hat{j}$ in magnetic field $\vec{B} = B_o\hat{i}$. The coordinates of the particle at time $t = \frac{\pi}{B_o\alpha}$ are (specific charge α = q/m)
(A) $\left(\frac{V_o}{2B_o\alpha}, \frac{\sqrt{2}V_o}{\alpha B_o}, \frac{-V_o}{B_o\alpha}\right)$ (B) $\left(\frac{-V_o}{2B_o\alpha}, 0, 0\right)$
(C) $\left(0, \frac{2V_o}{B_o\alpha}, \frac{V_o\pi}{2B_o\alpha}\right)$ (D) $\left(\frac{V_o\pi}{B_o\alpha}, 0, -\frac{2V_o}{B_o\alpha}\right)$

Q.28 Three ions H^+, He^+ and O^{+2} having same kinetic energy pass through a region in which there is a uniform magnetic field perpendicular to their velocity, then :
(A) H^+ will be least deflected. (B) He^+ and O^{+2} will be deflected equally.
(C) O^{+2} will be deflected most. (D) all will be deflected equally.

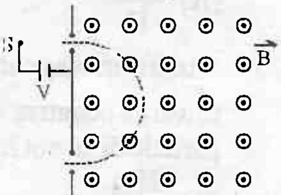
Q.29 An electron having kinetic energy T is moving in a circular orbit of radius R perpendicular to a uniform magnetic induction $\vec{B}$. If kinetic energy is doubled and magnetic induction tripled, the radius will become
(A) $\frac{3R}{2}$ (B) $\sqrt{\frac{3}{2}}\,R$ (C) $\sqrt{\frac{2}{9}}\,R$ (D) $\sqrt{\frac{4}{3}}\,R$

Q.30 An electron (mass = 9.1×10^{-31} ; charge = -1.6×10^{-19} C) experiences no deflection if subjected to an electric field of 3.2×10^5 V/m and a magnetic field of 2.0×10^{-3} Wb/m^2. Both the fields are normal to the path of electron and to each other. If the electric field is removed, then the electron will revolve in an orbit of radius :
(A) 45 m (B) 4.5 m (C) 0.45 m (D) 0.045 m

Q.31 A charged particle moves in a magnetic field $\vec{B} = 10\hat{i}$ with initial velocity $\vec{u} = 5\hat{i} + 4\hat{j}$. The path of the particle will be
(A) straight line (B) circle (C) helical (D) none

Q.32 A electron experiences a force $(4.0\hat{i} + 3.0\hat{j}) \times 10^{-13}$ N in a uniform magnetic field when its velocity is $2.5\hat{k} \times 10^7$ ms^{-1}. When the velocity is redirected and becomes $(1.5\hat{i} - 2.0\hat{j}) \times 10^7$ ms^{-1}, the magnetic force of the electron is zero. The magnetic field vector $\vec{B}$ is :
(A) $-0.075\hat{i} + 0.1\hat{j}$ (B) $0.1\hat{i} + 0.075\hat{j}$ (C) $0.075\hat{i} - 0.1\hat{j} + \hat{k}$ (D) $0.075\hat{i} - 0.1\hat{j}$

Q.33 A mass spectrometer is a device which select particle of equal mass. An iron with electric charge q > 0 and mass m starts at rest from a source S and is accelerated through a potential difference V It passes through a hole into a region of constant magnetic field $\vec{B}$ perpendicular to the plane of the paper as shown in the figure. The particle is deflected by the magnetic field and emerges through the bottom hole at a distance d from the top hole. The mass of the particle is

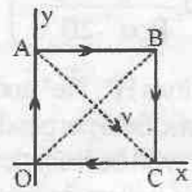


(A) $\frac{qBd}{mV}$ (B) $\frac{qB^2d^2}{4V}$ (C) $\frac{qB^2d^2}{8V}$ (D) $\frac{qBd}{2mV}$

Q.34 Electrons moving with different speeds enter a uniform magnetic field in a direction perpendicular to the field. They will move along circular paths.
(A) of same radius
(B) with larger radii for the faster electrons
(C) with smaller radii for the faster electrons
(D) either (B) or (C) depending on the magnitude of the magnetic field

Q.35 In the previous question, time periods of rotation will be :
(A) same for all electrons
(B) greater for the faster electrons
(C) smaller for the faster electrons
(D) either (B) or (C) depending on the magnitude of the magnetic field

Q.36 OABC is a current carrying square loop an electron is projected from the centre of loop along its diagonal AC as shown. Unit vector in the direction of initial acceleration will be



(A) $\hat{k}$ (B) $-\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$
(C) $-\hat{k}$ (D) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

Q.37 A particle having charge of 1 C, mass 1 kg and speed 1 m/s enters a uniform magnetic field, having magnetic induction of 1 T, at an angle $\theta = 30°$ between velocity vector and magnetic induction. The pitch of its helical path is (in meters)
(A) $\frac{\sqrt{3}\pi}{2}$ (B) $\sqrt{3}\pi$ (C) $\frac{\pi}{2}$ (D) π

Q.38 A charged particle is released from rest in a region of uniform electric and magnetic fields, which are parallel to each other. The locus of the particle will be
(A) helix of constant pitch (B) straight line
(C) helix of varying pitch (D) cycloid

Q.39 A particle of specific charge (charge/mass) α starts moving from the origin under the action of an electric field $\vec{E} = E_0\hat{i}$ and magnetic field $\vec{B} = B_0\hat{k}$. Its velocity at $(x_0, y_0, 0)$ is $(4\hat{i} + 3\hat{j})$. The value of x_0 is:

(A) $\frac{13\,\alpha E_0}{2\,B_0}$ (B) $\frac{16\alpha B_0}{E_0}$ (C) $\frac{25}{2\alpha E_0}$ (D) $\frac{5\alpha}{2B_0}$

Q.40 A particle of specific charge (q/m) is projected from the origin of coordinates with initial velocity $[u\mathrm{i} - v\mathrm{j}]$. Uniform electric magnetic fields exist in the region along the +y direction, of magnitude E and B. The particle will definitely return to the origin once if

(A) $[vB/2\pi E]$ is an integer (B) $(u^2 + v^2)^{1/2}\,[B/\pi E]$ is an integer
(C) $[vB/\pi E]$ in an integer (D) $[uB/\pi E]$ is an integer

Q.41 An electron moving with a velocity $\vec{V}_1 = 2\hat{i}$ m/s at a point in a magnetic field experiences a force $\vec{F}_1 = -2\hat{j}$ N. If the electron is moving with a velocity $\vec{V}_2 = 2\hat{j}$ m/s at the same point, it experiences a force $\vec{F}_2 = +2\hat{i}$ N. The force the electron would experience if it were moving with a velocity $\vec{V}_3 = 2\hat{k}$ m/s at the same point is

(A) zero (B) $2\hat{k}$N (C) $-2\hat{k}$N (D) information is insufficient

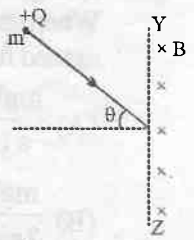
Q.42 Two particles of charges +Q and –Q are projected from the same point with a velocity v in a region of uniform magnetic field B such that the velocity vector makes an angle q with the magnetic field. Their masses are M and 2M, respectively. Then, they will meet again for the first time at a point whose distance from the point of projection is

(A) $2\pi Mv\cos\theta/QB$ (B) $8\pi Mv\cos\theta/QB$ (C) $\pi Mv\cos\theta/QB$ (D) $4\pi Mv\cos\theta/QB$

Q.43 A particle of charge Q and mass M moves in a circular path of radius R in a uniform magnetic field of magnitude B. The same particle now moves with the same speed in a circular path of same radius R in the space between the cylindrical electrodes of the cylindrical capacitor. The radius of the inner electrode is R/2 while that of the outer electrode is 3R/2. Then the potential difference between the capacitor electrodes must be

(A) $QBR(\ln 3)/M$ (B) $QB^2R^2(\ln 3)/2M$ (C) $QB^2R^2(\ln 3)/M$ (D) None

Q.44 A particle with charge +Q and mass m enters a magnetic field of magnitude B, existing only to the right of the boundary YZ. The direction of the motion of the particle is perpendicular to the direction of B. Let $T = 2\pi\frac{m}{QB}$. The time spent by the particle in the field will be

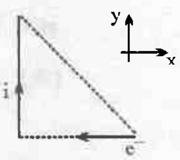


(A) $T\theta$ (B) $2T\theta$ (C) $T\left(\frac{\pi+2\theta}{2\pi}\right)$ (D) $T\left(\frac{\pi-2\theta}{2\pi}\right)$

Q.45 In the previous question, if the particle has –Q charge, the time spend by the particle in the field will be

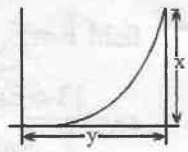
(A) $T\theta$ (B) $2T\theta$ (C) $T\left(\frac{\pi+2\theta}{2\pi}\right)$ (D) $T\left(\frac{\pi-2\theta}{2\pi}\right)$

Q.46 The direction of magnetic force on the electron as shown in the diagram is along



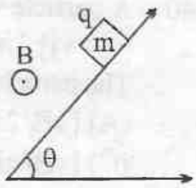
(A) y-axis (B) –y-axis
(C) z-axis (D) –z-axis

Q.47 A particle having charge q enters a region of uniform magnetic field $\vec{B}$ (directed inwards) and is deflected a distance x after travelling a distance y. The magnitude of the momentum of the particle is:



(A) $\frac{qBy}{2}$ (B) $\frac{qBy}{x}$ (C) $\frac{qB}{2}\left(\frac{y^2}{x}+x\right)$ (D) $\frac{qBy^2}{2x}$

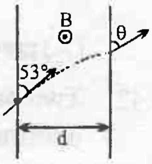
Q.48 A block of mass m & charge q is released on a long smooth inclined plane magnetic field B is constant, uniform, horizontal and parallel to surface as shown. Find the time from start when block loses contact with the surface.



(A) $\frac{m\cos\theta}{qB}$ (B) $\frac{m\,\text{cosec}\,\theta}{qB}$

(C) $\frac{m\cot\theta}{qB}$ (D) none

Q.49 A particle moving with velocity v having specific charge (q/m) enters a region of magnetic field B having width $d = \frac{3mv}{5qB}$ at angle 53° to the boundary of magnetic field. Find the angle θ in the diagram.



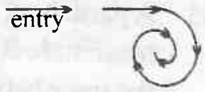
(A) 37° (B) 60° (C) 90° (D) none

Q.50 A charged particle enters a uniform magnetic field perpendicular to its initial direction travelling in air. The path of the particle is seen to follow the path in figure. Which of statements 1–3 is/are correct?

[1] The magnetic field strength may have been increased while the particle was travelling in air

[2] The particle lost energy by ionising the air

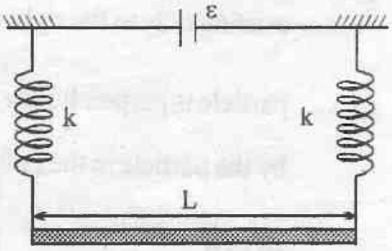
[3] The particle lost charge by ionising the air



(A) 1, 2, 3 are correct (B) 1, 2 only are correct

(C) 2, 3 only are correct (D) 1 only

Q.51 A straight rod of mass m and length L is suspended from the identical spring as shown in the figure. The spring stretched by a distance of x_0 due to the weight of the wire. The circuit has total resistance RΩ. When the magnetic field perpendicular to the plane of the paper is switched on, springs are observed to extend further by the same distance. The magnetic field strength is



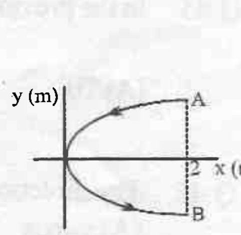
(A) $\frac{mgR}{\varepsilon L}$; directed outward from the plane of the paper

(B) $\frac{mgR}{2\varepsilon x_0}$; directed outward from the plane of the paper

(C) $\frac{mgR}{\varepsilon L}$; directed into the plane of the paper

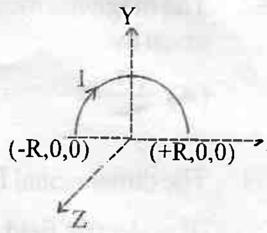
(D) $\frac{mgR}{\varepsilon x_0}$; directed into the plane of the paper

Q.52 A conducting wire bent in the form of a parabola $y^2 = 2x$ carries a current i = 2 A as shown in figure. This wire is placed in a uniform magnetic field $\vec{B} = -4\hat{k}$ Tesla. The magnetic force on the wire is (in newton)



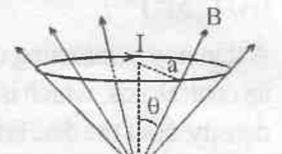
(A) $-16\hat{i}$ (B) $32\hat{i}$ (C) $-32\hat{i}$ (D) $16\hat{i}$

Q.53 A semi circular current carrying wire having radius R is placed in x-y plane with its centre at origin 'O'. There is non-uniform magnetic field $\vec{B} = \frac{B_o x}{2R}\hat{k}$ (here B_o is +ve constant) is existing in the region. The magnetic force acting on semi circular wire will be along



(A) – x-axis
(B) + y-axis
(C) – y-axis
(D) + x-axis

Q.54 A circular current loop of radius a is placed in a radial field B as shown. The net force acting on the loop is

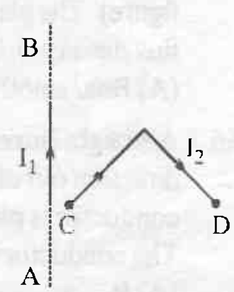


(A) zero
(B) $2\pi BaI\cos\theta$
(C) $2\pi aIB\sin\theta$
(D) None

Q.55 A conductor of length l and mass m is placed along the east-west line on a table. Suddenly a certain amount of charge is passed through it and it is found to jump to a height h. The earth's magnetic induction is B. The charge passed through the conductor is:

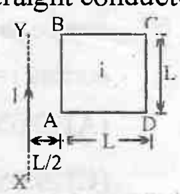
(A) $\frac{1}{Bmgh}$ (B) $\frac{\sqrt{2gh}}{Blm}$ (C) $\frac{gh}{Blm}$ (D) $\frac{m\sqrt{2gh}}{Bl}$

Q.56 In the figure shown a current I_1 is established in the long straight wire AB. Another wire CD carrying current I_2 is placed in the plane of the paper. The line joining the ends of this wire is perpendicular to the wire AB. The force on the wire CD is:



(A) zero
(B) towards left
(C) directed upwards
(D) none of these

Q.57 A square loop ABCD, carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be

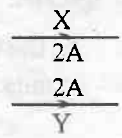


(A) $\frac{2\mu_0 Ii}{3\pi}$ (B) $\frac{\mu_0 Ii}{2\pi}$ (C) $\frac{2\mu_0 Iil}{3\pi}$ (D) $\frac{\mu_0 Iil}{2\pi}$

Q.58 A metal ring of radius r = 0.5 m with its plane normal to a uniform magnetic field B of induction 0.2 T carries a current I = 100 A. The tension in newtons developed in the ring is:

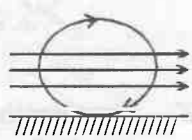
(A) 100 (B) 50 (C) 25 (D) 10

Q.59 In given figure, X and Y are two long straight parallel conductors each carrying a current of 2 A. The force on each conductor is F newtons. When the current in each is changed to 1 A and reversed in direction, the force on each is now



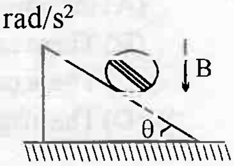
(A) F/4 and unchanged in direction
(B) F/2 and reversed in direction
(C) F/2 and unchanged in direction
(D) F/4 and reversed in direction

Q.60 A conducting ring of mass 2 kg and radius 0.5 m is placed on a smooth horizontal plane. The ring carries a current i = 4A. A horizontal magnetic field B = 10T is switched on at time t = 0 as shown in figure. The initial angular acceleration of the ring will be



(A) 40 π rad/s² (B) 20 π rad/s² (C) 5 π rad/s² (D) 15 π rad/s²

Q.61 In the figure shown a coil of single turn is wound on a sphere of radius R and mass m. The plane of the coil is parallel to the plane and lies in the equatorial plane of the sphere. Current in the coil is i. The value of B if the sphere is in equilibrium is



(A) $\frac{mg\cos\theta}{\pi iR}$ (B) $\frac{mg}{\pi iR}$ (C) $\frac{mg\tan\theta}{\pi iR}$ (D) $\frac{mg\sin\theta}{\pi iR}$

Q.62 The magnetic moment of a circular orbit of radius 'r' carrying a charge 'q' and rotating with velocity v is given by

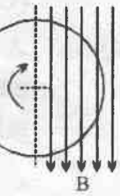
(A) $\frac{qvr}{2\pi}$ (B) $\frac{qvr}{2}$ (C) $qv\pi r$ (D) $qv\pi r^2$

Q.63 The dimensional formula for the physical quantity $\frac{E^2\mu_0\varepsilon_0}{B^2}$ is

(E = electric field and B = magnetic field)

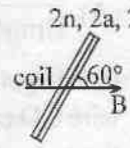
(A) $L^0M^0T^0$ (B) $L^1M^0T^{-1}$ (C) $L^{-1}M^0T^1$ (D) $L^{1/2}M^0T^{-1/2}$

Q.64 A thin non conducting disc of radius R is rotating clockwise (see figure) with an angular velocity w about its central axis, which is perpendicular to its plane. Both its surfaces carry +ve charges of uniform surface density. Half the disc is in a region of a uniform, unidirectional magnetic field B parallel to the plane of the disc, as shown. Then,



(A) The net torque on the disc is zero.
(B) The net torque vector on the disc is directed leftwards.
(C) The net torque vector on the disc is directed rightwards.
(D) The net torque vector on the disc is parallel to B.

Q.65 A rectangular coil PQ has 2n turns, an area 2a and carries a current 2*I*, (refer figure). The plane of the coil is at 60° to a horizontal uniform magnetic field of flux density B. The torque on the coil due to magnetic force is



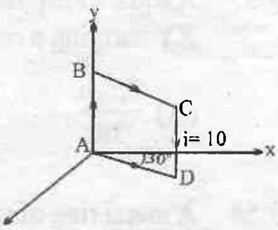
(A) Bna*I* sin60° (B) 8Bna*I* cos60° (C) 4na*I* Bsin60° (D) none

Q.66 A straight current carrying conductor is placed in such a way that the current in the conductor flows in the direction out of the plane of thc paper. The conductor is placed between two poles of two magnets, as shown. The conductor will experience a force in the direction towards



(A) P (B) Q (C) R (D) S

Q.67 Figure shows a square current carrying loop ABCD of side 10 cm and current i = 10A. The magnetic moment $\vec{M}$ of the loop is



(A) $(0.05)\left(\hat{i}-\sqrt{3}\hat{k}\right)A-m^2$ (B) $(0.05)\left(\hat{j}+\hat{k}\right)A-m^2$

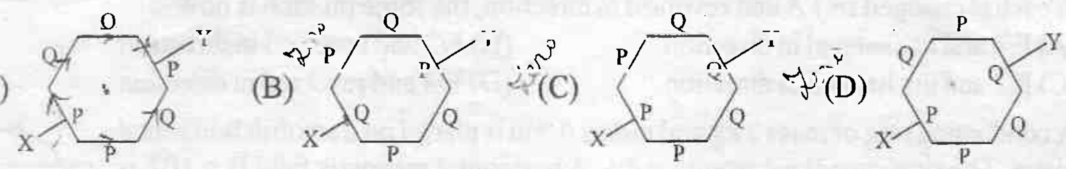
(C) $(0.05)\left(\sqrt{3}\hat{i}+\hat{k}\right)A-m^2$ (D) $\left(\hat{i}+\hat{k}\right)A-m^2$

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 In the following hexagons, made up of two different material P and Q, current enters and leaves from points X and Y respectively. In which case the magnetic field at its centre is not zero.

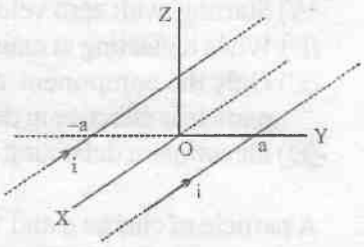
(A) (B) (C) (D)



Q.2 Consider the magnetic field produced by a finitely long current carrying wire.
(A) the lines of field will be concentric circles with centres on the wire.
(B) There can be two points in the same plane where magnetic fields are same.
(C) There can be large number of points where the magnetic field is same.
(D) The magnetic field at a point is inversally proportional to the distance of the point from the wire.

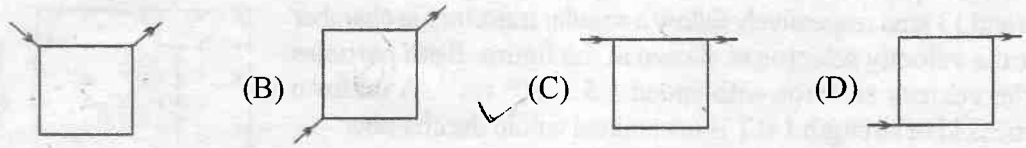
Q.3 Consider three quantities $x = E/B$, $y = \sqrt{1/\mu_0\varepsilon_0}$ and $z = \frac{l}{CR}$. Here, l is the length of a wire, C is a capacitance and R is a resistance. All other symbols have standard meanings.
(A) x, y have the same dimensions
(B) y, z have the same dimensions
(C) z, x have the same dimensions
(D) none of the three pairs have the same dimensions.

Q.4 Two long thin, parallel conductors carrying equal currents in the same direction are fixed parallel to the x-axis, one passing through y = a and the other through y = –a. The resultant magnetic field due to the two conductors at any point is B. Which of the following are correct?

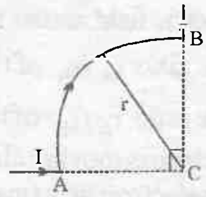


(A) B = 0 for all points on the x-axis
(B) At all points on the y-axis, excluding the origin, B has only a z-component.
(C) At all points on the z-axis, excluding the origin, B has only a y-component.
(D) B cannot have an x-component.

Q.5 Current flows through uniform, square frames as shown. In which case is the magnetic field at the centre of the frame not zero?



Q.6 A wire carrying I is shaped as shown. Section AB is a quarter circle of radius r. The magnetic field at C is directed
(A) along the bisector of the angle ACB, away from AB
(B) along the bisector of the angle ACB, towards AB
(C) perpendicular to the plane of the paper, directed into the paper
(D) at an angle $\pi/4$ to the plane of the paper



Q.7 A long straight wire carries a current along the x-axis. Consider the points A(0, 1, 0), B(0, 1, 1), C(1, 0, 1) and D(1, 1, 1). Which of the following pairs of points will have magnetic fields of the same magnitude?
(A) A and B
(B) A and C
(C) B and C
(D) B and D

Q.8 In the previous question, if the current is i and the magnetic field at D has magnitude B,
(A) $B = \frac{\mu_0 i}{2\sqrt{2}\pi}$
(B) $B = \frac{\mu_0 i}{2\sqrt{3}\pi}$
(C) B is parallel to the x-axis
(D) B makes an angle of 45° with the xy plane

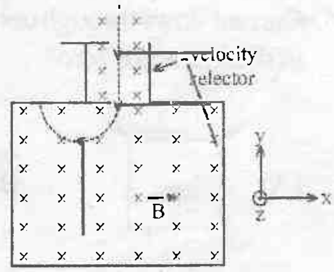
Q.9 Which of the following statement is correct :
(A) A charged particle enters a region of uniform magnetic field at an angle 85^0 to magnetic lines of force. The path of the particle is a circle.
(B) An electron and proton are moving with the same kinetic energy along the same direction. When they pass through uniform magnetic field perpendicular to their direction of motion, they describe circular path.
(C) There is no change in the energy of a charged particle moving in a magnetic field although magnetic force acts on it.
(D) Two electrons enter with the same speed but in opposite direction in a uniform transverse magnetic field. Then the two describe circle of the same radius and these move in the same direction.

Q.10 Two identical charged particles enter a uniform magnetic field with same speed but at angles 30° and 60° with field. Let a, b and c be the ratio of their time periods, radii and pitches of the helical paths than
(A) abc = 1 (B) abc > 1 (C) abc < 1 (D) a = bc

Q.11 Consider the following statements regarding a charged particle in a magnetic field . Which of the statements are true :
(A) Starting with zero velocity, it accelerates in a direction perpendicular to the magnetic field.
(B) While deflecting in magnetic field its energy gradually increases .
(C) Only the component of magnetic field perpendicular to the direction of motion of the charged particle is effective in deflecting it.
(D) Direction of deflecting force on the moving charged particle is perpendicular to its velocity.

Q.12 A particle of charge q and velocity v passes undeflected through a space with non-zero electric field E and magnetic field B. The undeflecting conditions will hold if.
(A) signs of both q and E are reversed.
(B) signs of both q and B are reversed.
(C) both B and E are changed in magnitude, but keeping the product of |B| and |E| fixed.
(D) both B and E are doubled in magnitude.

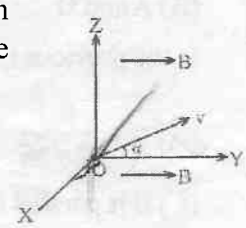
Q.13 Two charged particle A and B each of charge +e and masses 12 amu and 13 amu respectively follow a circular trajectory in chamber X after the velocity selector as shown in the figure. Both particles enter the velocity selector with speed 1.5×10^6 ms^{-1}. A uniform magnetic field of strength 1.0 T is maintained within the chamber X and in the velocity selector.



(A) Electric field across the conducting plate of the velocity selector is -10^6 NC^{-1} $\hat{i}$.
(B) Electric field across the conducting plate of the velocity selector is 10^6 NC^{-1} $\hat{i}$.
(C) The ratio r_A/r_B of the radii of the circular paths for the two particles is 12/13.
(D) The ratio r_A/r_B of the radii of the circular paths for the two particles is 13/12.

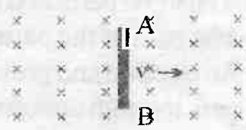
Q.14 An electron is moving along the positive X-axis. You want to apply a magnetic field for a short time so that the electron may reverse its direction and move parallel to the negative X–axis. This can be done by applying the magnetic field along
(A) Y-axis (B) Z-axis (C) Y-axis only (D) Z-axis only

Q.15 In a region of space, a uniform magnetic field B exists in the y-direction. A proton is fired from the origin, with its initial velocity v making a small angle α with the y-direction in the yz plane. In the subsequent motion of the proton,



(A) its x-coordinate can never be positive
(B) its x- and z-coordinates cannot both be zero at the same time
(C) its z-coordinate can never be negative
(D) its y-coordinate will be proportional to the square of its time of flight

Q.16 A rod AB moves with a uniform velocity v in a uniform magnetic field as shown in figure.



(A) The rod becomes electrically charged.
(B) The end A becomes positively charged.
(C) The end B becomes positively charged.
(D) The rod becomes hot because of Joule heating.

Question No. 17 to 21 (5 questions)

The following experiment was performed by J.J.Thomson in order to measure the ratio of the charge e to the mass m of an electron. Figure shows a modern version of Thomson's apparatus. Electrons emitted from a hot filament are accelerated by a potential difference V. As the electrons pass through the deflector plates, they encounter both electric and magnetic fields. When the electrons leave the plates they enter a field-free region that extends to the fluorescent screen. The beam of electrons can be observed as a spot of light on the screen. The entire region in which the electrons travel is evacuated with a vacuum pump.

Thomson's procedure was to first set both the electric and magnetic fields to zero, note the position of the undeflected electron beam on the screen, then turn on only the electric field and measure the resulting deflection. The deflection of an electron in an electric field of magnitude E is given by $d_1=eEL^2/2mv^2$, where L is the length of the deflecting plates, and v is the speed of the electron. The deflection d_1 can also be calculated from the total deflection of the spot on the screen, $d_1 + d_2$ and the geometry of the apparatus. In the second part of the experiment, Thomson adjusted the magnetic field so as to exactly cancel the force applied by the electric field, leaving the electron beam undeflected. This gives eE = evB. By combining this relation with the expression for d_1, one can calculate the charge to mass ratio of the electron as a function of the known quantities. The result is:

$$\frac{e}{m}=\frac{2d_1E}{B^2L^2}$$

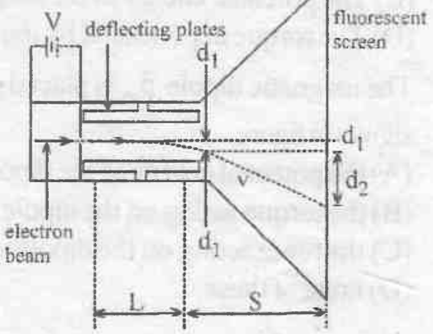
Q.17 Why was it important for Thomson to evacuate the air from the apparatus?

(A) Electrons travel faster in a vacuum, making the deflection d_1 smaller.

(B) Electromagnetic waves propagate in a vacuum.

(C) The electron collisions with the air molecules cause them to be scattered, and a focused beam will not be produced.

(D) It was not important and could have been avoided.



Q.18 One might have considered a different experiment in which no magnetic field is needed. The ratio e/m can then be calculated directly from the expression for d_1. Why might Thomson have introduced the magnetic field B in his experiment?

(A) To verify the correctness of the equation for the magnetic force.

(B) To avoid having to measure the electron speed v.

(C) To cancel unwanted effects of the electric field E.

(D) To make sure that the electric field does not exert a force on the electron.

Q.19 If the electron speed were doubled by increasing the potential difference V, which of the following would have to be true in order to correctly measure e/m?

(A) The magnetic field would have to be cut in half in order to cancel the force applied by the electric field.

(B) The magnetic field would have to be doubled in order to cancel the force applied by the electric field.

(C) The length of the plates, L, would have to be doubled to keep the deflection, d_1, from changing.

(D) Nothing needs to be changed.

Q.20 The potential difference V. which accelerates the electrons, also creates an electric field. Why did Thomson NOT consider the deflection caused this electric field in his experiment?

(A) This electric field is much weaker than the one between the deflecting plates and can be neglected.

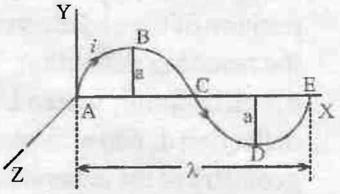
(B) Only the deflection, $d_1 + d_2$ caused by the deflecting plates is measured in the experiment.

(C) There is no deflection from this electric field

(D) The magnetic field cancels the force caused by this electric field.

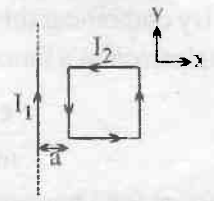
Q.21 If the electron is deflected downward when only the electric field is turned on (as shown in figure) then in what directions do the electric and magnetic fields point in the second part of the experiment?
(A) The electric field points to the bottom, while the magnetic field points into the page.
(B) The electric field points to the bottom, while the magnetic field points out of the page.
(C) The electric field points to the top, while the magnetic field points into the page.
(D) The electric field points to the top, while the magnetic field points out of the page.

Q.22 A conductor ABCDE, shaped as shown, carries a current i. It is placed in the xy plane with the ends A and E on the x-axis. A uniform magnetic field of magnitude B exists in the region. The force acting on it will be



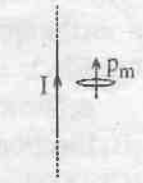
(A) zero, if B is in the x-direction
(B) $\lambda B i$ in the z-direction, if B is in the y-direction
(C) $\lambda B i$ in the negative y-direction, if B is in the z-direction
(D) $2aBi$, if B is in the x-direction

Q.23 A square loop of side ℓ is placed in the neighbourhood of an infinitely long straight wire carrying a current I_1. The loop carries a current I_2 as shown in figure



(A) The magnetic moment of the loop is $\vec{p}_m = l^2 I_2 \hat{k}$
(B) The magnetic moment of the loop is $\vec{p}_m = -l^2 I_2 \hat{k}$
(C) The potential energy of the loop is minimum
(D) The torque experienced by the loop is maximum

Q.24 The magnetic dipole $\vec{p}_m$ is placed parallel to an infinitely long straight wire as shown in figure



(A) the potential energy of the dipole is minimum
(B) the torque acting on the dipole is zero
(C) the force acting on the dipole is zero
(D) none of these

ANSWER KEY

ONLY ONE OPTION IS CORRECT.

Q.1	D	Q.2	C	Q.3	C	Q.4	A	Q.5	A	Q.6	A	Q.7	D
Q.8	A	Q.9	A	Q.10	B	Q.11	B	Q.12	C	Q.13	A	Q.14	A
Q.15	B	Q.16	A	Q.17	C	Q.18	A	Q.19	B	Q.20	B	Q.21	A
Q.22	B	Q.23	D	Q.24	D	Q.25	B	Q.26	A	Q.27	D	Q.28	B
Q.29	C	Q.30	C	Q.31	C	Q.32	A	Q.33	C	Q.34	B	Q.35	A
Q.36	B	Q.37	B	Q.38	B	Q.39	C	Q.40	C	Q.41	A	Q.42	D
Q.43	C	Q.44	C	Q.45	D	Q.46	A	Q.47	C	Q.48	C	Q.49	C
Q.50	B	Q.51	A	Q.52	B	Q.53	A	Q.54	C	Q.55	D	Q.56	D
Q.57	A	Q.58	D	Q.59	A	Q.60	A	Q.61	B	Q.62	B	Q.63	A
Q.64	B	Q.65	B	Q.66	B	Q.67	A						

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	A	Q.2	A,B,C	Q.3	A,B,C	Q.4	A,B,C,D
Q.5	C	Q.6	C	Q.7	B,D	Q.8	A,D
Q.9	B,C	Q.10	A,D	Q.11	C,D	Q.12	D
Q.13	C	Q.14	A,B	Q.15	A	Q.16	B
Q.17	C	Q.18	B	Q.19	A	Q.20	C
Q.21	D	Q.22	A,B,C	Q.23	A	Q.24	C

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (PQRS & J)

QUESTION BANK ON

MECHANICAL WAVES

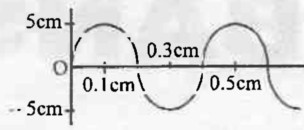
Time Limit : 2 Sitting Each of 90 minutes. duration approx.

Objective Question Bank On Mechanical Waves

There are 76 questions in this question bank.

Q.1 An open organ pipe of length L vibrates in second harmonic mode. The pressure vibration is maximum
(A) at the two ends
(B) at a distance L/4 from either end inside the tube
(C) at the mid-point of the tube
(D) none of these

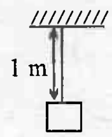
Q.2 Figure shown the shape of part of a long string in which transverse waves are produced by attaching one end of the string to tuning fork of frequency 250 Hz. What is the velocity of the waves?



(A) 1.0 ms^{-1}
(B) 1.5 ms^{-1}
(C) 2.0 ms^{-1}
(D) 2.5 ms^{-1}

Q.3 A sinusoidal progressive wave is generated in a string. It's equation is given by $y = (2\ mm)\sin(2\pi x - 100\pi t + \pi/3)$. The time when particle at x = 4 m first passes through mean position, will be
(A) $\frac{1}{150}$ sec
(B) $\frac{1}{12}$ sec
(C) $\frac{1}{300}$ sec
(D) $\frac{1}{100}$ sec

Q.4 A block of mass 1 kg is hanging vertically from a string of length 1 m and mass/length = 0.001 Kg/m. A small pulse is generated at its lower end. The pulse reaches the top end in approximately



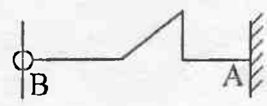
(A) 0.2 sec
(B) 0.1 sec
(C) 0.02 sec
(D) 0.01 sec

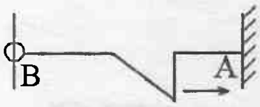
Q.5 Find the resultant of 2 wave progressing along x-axis.

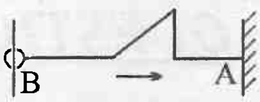
$$y_1 = 3\sin(3t - 6x)$$
$$y_2 = -4\cos(3t - 6x)$$

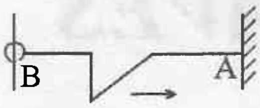
(A) $5\sin(3t - 6x - 37°)$
(B) $5\sin(3t - 6x + 53°)$
(C) $5\sin(3t - 6x - 53°)$
(D) None

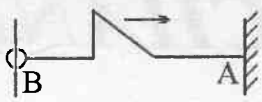
Q.6 A pulse shown here is reflected from the rigid wall A and then from free end B. The shape of the string after these 2 reflection will be



(A)


(B)


(C)


(D)


Q.7 An open organ pipe of length l is sounded together with another organ pipe of length $l + x$ in their fundamental tones ($x << l$). The beat frequency heard will be (speed of sound is v) :
(A) $\frac{vx}{4l^2}$
(B) $\frac{vl^2}{2x}$
(C) $\frac{vx}{2l^2}$
(D) $\frac{vx^2}{2l}$

Q.8 A taut string at both ends vibrates in its nth overtone. The distance between adjacent Node and Antinode is found to be 'd'. If the length of the string is L, then
(A) L = 2d (n + 1)
(B) L = d (n + 1)
(C) L = 2dn
(D) L = 2d (n – 1)

Q.9 Two waves are propagating along a taut string that coincides with the x-axis. The first wave has the wave function $y_1 = A\cos[k(x - vt)]$ and the second has the wave function $y = A\cos[k(x + vt) + \phi]$.
(A) For constructive interference at $x = 0, \phi = \pi$.
(B) For constructive interference at $x = 0, \phi = 3\pi$.
(C) For destructive interference at $x = 0, \phi = \pi$.
(D) For destructive interference at $x = 0, \phi = 2\pi$.

Q.10 The second overtone of an open organ pipe A and a closed pipe B have the same frequency at a given temperature. It follows that the ratio of the
(A) length of A and B is 4 : 3
(B) fundamental frequencies of A & B is 5 : 6
(C) lengths of B to that of A is 5 : 6
(D) frequencies of first overtone of A & B is 10 : 9

Q.11 The length, tension, diameter and density of a wire B are double than the corresponding quantities for another stretched wire A. Then.
(A) Fundamental frequency of B is $\frac{1}{2\sqrt{2}}$ times that of A.
(B) The velocity of wave in B is $\frac{1}{\sqrt{2}}$ times that of velocity in A.
(C) The fundamental frequency of A is equal to the third overtone of B.
(D) The velocity of wave in B is half that of velocity in A.

Q.12 A tuning fork of frequency 280 Hz produces 10 beats per sec when sounded with a vibrating sonometer string. When the tension in the string increases slightly, it produces 11 beats per sec. The original frequency of the vibrating sonometer string is :
(A) 269 Hz (B) 291 Hz (C) 270 Hz (D) 290 Hz

Q.13 Two whistles A and B each have a frequency of 500Hz. A is stationary and B is moving towards the right (away from A) at a speed of 50 m/s. An observer is between the two whistles moving towards the right with a speed of 25 m/s. The velocity of sound in air is 350 m/s. Assume there is no wind. Then which of the following statements are true:
(A) The apparent frequency of whistle B as heard by A is 444Hz approximately
(B) The apparent frequency of whistle B as heard by the observer is 469Hz approximately
(C) The difference in the apparent frequencies of A and B as heard by the observer is 4.5 Hz.
(D) The apparent frequencies of the whistles of each other as heard by A and B are the same.

Q.14 A string 1m long is drawn by a 300Hz vibrator attached to its end. The string vibrates in 3 segments. The speed of transverse waves in the string is equal to
(A) 100 m/s (B) 200 m/s (C) 300 m/s (D) 400 m/s

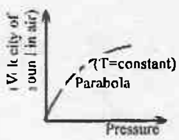
Q.15 A string vibrates in 5 segments to a frequency of 480 Hz. The frequency that will cause it to vibrate in 2 segments will be
(A) 96 Hz (B) 192 Hz (C) 1200 Hz (D) 2400 Hz

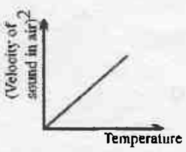
Q.16 Two tuning forks A & B produce notes of frequencies 256 Hz & 262 Hz respectively. An unknown note sounded at the same time as A produces beats. When the same note is sounded with B, beat frequency is twice as large. The unknown frequency could be :
(A) 268 Hz (B) 260 Hz (C) 250 Hz (D) 242 Hz

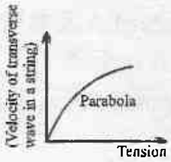
Q.17 A transverse wave is described by the equation $y = A \sin [2\pi (ft - x/\lambda)]$. The maximum particle velocity is equal to four times the wave velocity if:
(A) $\lambda = \pi A/4$ (B) $\lambda = \pi A/2$ (C) $\lambda = \pi A$ (D) $\lambda = 2\pi A$

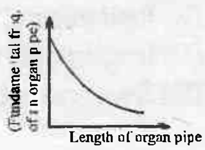
Q.18 A wave is propagating along x-axis. The displacement of particles of the medium in z-direction at $t = 0$ is given by: $z = \exp[-(x+2)^2]$, where 'x' is in meters. At $t = 1$ s, the same wave disturbance is given by: $z = \exp[-(2-x)^2]$. Then, the wave propagation velocity is
(A) 4 m/s in +x direction (B) 4 m/s in –x direction
(C) 2 m/s in + x direction (D) 2 m/s in – x direction

Q.19 Which of the following graphs is/are correct.

(A) 

(B) 

(C) 

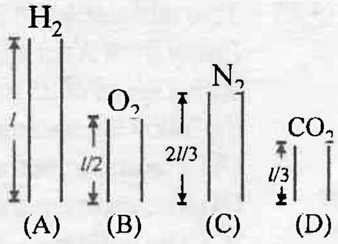
(D) 

Q.20 In a situation, wind is blowing from source to observer. The wavelength of sound heard by stationary observer in the medium due to sound produced by the fixed source.
(A) increases (B) decreases
(C) remains same (D) can't be determine

Q.21 In a test of subsonic Jet flies over head at an altitude of 100 m. The sound intensity on the ground as the Jet passes overhead is 160 dB. At what altitude should the plane fly so that the ground noise is not greater than 120 dB.
(A) above 10 km from ground (B) above 1 km from ground
(C) above 5 km from ground (D) above 8 km from ground

Q.22 The frequency changes by 10% as a sound source approaches a stationary observer with constant speed v_s. What would be the percentage change in frequency as the source recedes the observer with the same speed. Given that $v_s < v$. (v = speed of sound in air)
(A) 14.3% (B) 20% (C) 10.0% (D) 8.5%

Q.23 Four open organ pipes of different lengths and different gases at same temperature as shown in figure. Let f_A, f_B, f_C and f_D be their fundamental frequencies then :[Take $\gamma_{CO_2} = 7/5$]



(A) $f_A/f_B = \sqrt{2}$ (B) $f_B/f_C = \sqrt{72/28}$
(C) $f_C/f_D = \sqrt{11/28}$ (D) $f_D/f_A = \sqrt{76/11}$

Q.24 A sufficiently long close organ pipe has a small hole at its bottom. Initially the pipe is empty. Water is poured into the pipe at a constant rate. The fundamental frequency of the air column in the pipe
(A) continuously increasing (B) first increases and them becomes constant
(C) continuously decreases (D) first decreases and them become constant

Q.25 A tuning fork of frequency 340 Hz is vibrated just above a cylindrical tube of length 120 cm. Water is slowly poured in the tube. If the speed of sound is 340 ms^{-1} then the minimum height of water required for resonance is:
(A) 95 cm (B) 75 cm (C) 45 cm (D) 25 cm

Q.26 A metallic wire of length L is fixed between two rigid supports. If the wire is cooled through a temperature difference ΔT (Y = young's modulus, ρ = density, α = coefficient of linear expansion) then the frequency of transverse vibration is proportional to :

(A) $\frac{\alpha}{\sqrt{\rho Y}}$ (B) $\sqrt{\frac{Y\alpha}{\rho}}$ (C) $\frac{\rho}{\sqrt{Y\alpha}}$ (D) $\sqrt{\frac{\rho\alpha}{Y}}$

Q.27 A source of sound moves towards an observer
(A) the frequency of the source is increased.
(B) the velocity of sound in the medium is increased.
(C) the wavelength of sound in the medium towards the observer is decreased.
(D) the amplitude of vibration of the particles is increased.

Q.28 A string is fixed at both ends vibrates in a resonant mode with a separation 2.0 cm between the consecutive nodes. For the next higher resonant frequency, this separation is reduced to 1.6 cm. The length of the string is
(A) 4.0 cm (B) 8.0 cm (C) 12.0 cm (D) 16.0 cm

Q.29 A car moves towards a hill with speed v_c. It blows a horn of frequency f which is heared by an observer following the car with speed v_0. The speed of sound in air is v.

(A) the wavelength of sound reaching the hill is $\frac{v}{f}$

(B) the wavelength of sound reaching the hill is $\frac{v - v_c}{f}$

(C) the beat frequency observed by the observer is $\left(\frac{v + v_c}{v - v_c}\right)f$

(D) the beat frequency observed by the observer is $\frac{2v_c(v + v_o)f}{v^2 - v_c^2}$

Q.30 A gas is filled in an organ pipe and it is sounded with an organ pipe in fundamental mode. Choose the correct statement(s) : (T = constant)
(A) If gas is changed from H_2 to O_2, the resonant frequency will increase
(B) If gas is changed from O_2 to N_2, the resonant frequency will increase
(C) If gas is changed from N_2 to He, the resonant frequency will decrease
(D) If gas is changed from He to CH_4, the resonant frequency will decrease

Q.31 A composition string is made up by joining two strings of different masses per unit length → μ and 4μ. The composite string is under the same tension. A transverse wave pulse : Y = (6 mm) sin(5t + 40x), where 't' is in seconds and 'x' in meters, is sent along the lighter string towards the joint. The joint is at x = 0. The equation of the wave pulse reflected from the joint is
(A) (2 mm) sin(5t – 40x) (B) (4 mm) sin(40x – 5t)
(C) – (2 mm) sin(5t – 40x) (D) (2 mm) sin (5t – 10x)

Q.32 In the previous question, the percentage of power transmitted to the heavier string through the joint is approximately
(A) 33% (B) 89% (C) 67% (D) 75%

Q.33 A wave travels uniformly in all directions from a point source in an isotropic medium. The displacement of the medium at any point at a distance r from the source may be represented by
(A is a constant representing strength of source)
(A) $[A/\sqrt{r}]\sin(kr - \omega t)$ (B) $[A/r]\sin(kr - \omega t)$
(C) $[Ar]\sin(kr - \omega t)$ (D) $[A/r^2]\sin(kr - \omega t)$

Q.34 Three coherent waves of equal frequencies having amplitude 10 μm, 4μm and 7 μm respectively, arrive at a given point with successive phase difference of π/2. The amplitude of the resulting wave in mm is given by
(A) 5 (B) 6 (C) 3 (D) 4

Q.35 An organ pipe P_1 closed at one end vibrating in its first overtone. Another pipe P_2 open at both ends is vibrating in its third overtone. They are in a resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is :
(A) 8/3 (B) 3/8 (C) 1/2 (D) 1/3

Q.36 In a closed end pipe of length 105 cm, standing waves are set up corresponding to the third overtone. What distance from the closed end, amongst the following, is a pressure Node?
(A) 20 cm (B) 60 cm (C) 85 cm (D) 45 cm

Q.37 A pipe's lower end is immersed in water such that the length of air column from the top open end has a certain length 25 cm. The speed of sound in air is 350 m/s. The air column is found to resonate with a tuning fork of frequency 1750 Hz. By what minimum distance should the pipe be raised in order to make the air column resonate again with the same tuning fork?
(A) 7 cm (B) 5 cm (C) 35 cm (D) 10 cm

Q.38 The vibration of a string fixed at both ends are described by $Y = 2 \sin(\pi x) \sin(100\pi t)$ where Y is in mm, x is in cm, t in sec then
(A) Maximum displacement of the particle at x = 1/6 cm would be 1 mm.
(B) velocity of the particle at x = 1/6 cm at time t = 1/600 sec will be $157\sqrt{3}$ mm/s
(C) If the length of the string be 10 cm, number of loop in it would be 5
(D) None of these

Q.39 A perfectly elastic uniform string is suspended vertically with its upper end fixed to the ceiling and the lower end loaded with the weight. If a transverse wave is imparted to the lower end of the string, the pulse will
(A) not travel along the length of the string (B) travel upwards with increasing speed
(C) travel upwards with decreasing speed (D) travelled upwards with constant acceleration

Q.40 A wave is represented by the equation $y = 10 \sin 2\pi(100t-0.02x) + 10 \sin 2\pi(100t+0.02x)$.
The maximum amplitude and loop length are respectively
(A) 20 units and 30 units (B) 20 units and 25 units
(C) 30 units and 20 units (D) 25 units and 20 units

Q.41 The length, tension, diameter and density of a wire B are double than the corresponding quantities for another stretched wire A. Then
(A) fundamental frequency of B is $1/2\sqrt{2}$ times that of A.
(B) the velocity of wave in B is $1/\sqrt{2}$ times that of velocity in A.
(C) the fundamental frequency of A is equal to the third overtone of B.
(D) the velocity of wave in B is half that of velocity in A.

Q.42 A standing wave $y = A \sin\left(\frac{20}{3}\pi x\right) \cos(1000\pi t)$ is maintained in a taut string where y and x are expressed in meters. The distance between the successive points oscillating with the amplitude A/2 across a node is equal to
(A) 2.5cm (B) 25cm (C) 5cm (D) 10cm

Q.43 A plane wave $y = A \sin \omega\left(t - \frac{x}{v}\right)$ undergo a normal incidence on a plane boundary separating medium M_1 and M_2 and splits into a reflected and transmitted wave having speeds v_1 and v_2 then
(A) for all values of v_1 and v_2 the phase of transmitted wave is same as that of incident wave
(B) for all values of v_1 and v_2 the phase of reflected wave is same as that of incident wave
(C) the phase of transmitted wave depends upon v_1 and v_2
(D) the phase of reflected wave depends upon v_1 and v_2

Q.44 A wire under tension between two fixed points A and B, executes transverse vibrations in lowest mode so that the mid point O of AB is a node. Then
(A) all points of the wire between A and B are in the same phase
(B) all points between A and O are in the same phase
(C) any point between A and O and any point between O and B have a phase difference of $\pi/2$
(D) any point between A and O and any point between O and B have a phase difference of π.

Q.45 In case of closed organ pipe which harmonic the pth overtone will be
(A) $2p + 1$ (B) $2p - 1$ (C) $p + 1$ (D) $p - 1$

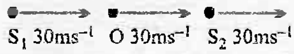
Q.46 A wave equation is given as $y = \cos(500t - 70x)$, where y is in mm, x in m adn t is in sec.
(A) the wave must be a transverse porpagating wave.
(B) The speed of the wave is 50/7 m/s
(C) The frequency of oscillations 1000π Hz
(D) Two closest points which are in same phase have separation $20\pi/7$ cm.

Q.47 Which of the following statements are wrong about the velocity of sound in air:
(A) decreases with increases in temperature (B) increases with decrease in temperature
(C) decreases as humidity increases (D) independent of density of air.

Q.48 A clamped string is oscillating in nth harmonic, then
(A) total energy of oscillations will be n^2 times that of fundamental frequency
(B) total energy of oscillations will be $(n-1)^2$ times that of fundamental frequency
(C) average kinetic energy of the string over a complete oscillations is half of that of the total energy of the string.
(D) none of these

Q.49 A string of length 1m and linear mass density $0.01 kgm^{-1}$ is stretched to a tension of 100N. When both ends of the string are fixed, the three lowest frequencies for standing wave are f_1, f_2 and f_3. When only one end of the string is fixed, the three lowest frequencies for standing wave are n_1, n_2 and n3. Then
(A) $n_3 = 5n_1 = f_3 = 125$ Hz (B) $f_3 = 5f_1 = n_2 = 125$ Hz
(C) $f_3 = n_2 = 3f_1 = 150$ Hz (D) $n_2 = \frac{f_1 + f_2}{2} = 75$ Hz

Q.50 Consider two sound sources S_1 and S_2 having same frequency 100Hz and the observer O located between them as shown in the fig. All the three are moving with same velocity in same direction. The beat frequency of the observer is



(A) 50Hz (B) 5 Hz (C) zero (D) 2.5 Hz

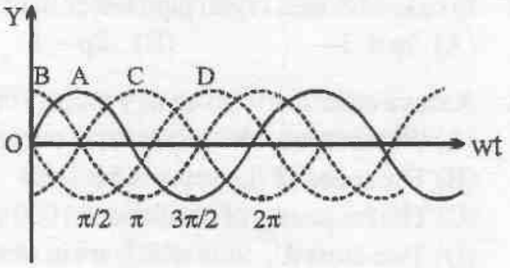
Q.51 A 2.0m long string with a linear mass density of 5.2×10^{-3} kg m^{-1} and tension 52N has both of its ends fixed. It vibrates in a standing wave pattern with four antinodes. Frequency of the vibration is
(A) 75 Hz (B) 150 Hz (C) 100 Hz (D) 50 Hz

Q.52 An isotropic point source emits sound of a single frequency. The amplitude of the sound wave at a distance r from the source is proportional to r^{-n}. The value of n is
(A) 2 (B) $\sqrt{2}$ (C) 1 (D) 1/2

Q.53 An engine whistling at a constant frequency n_0 and moving with a constant velocity goes past a stationary observer. As the engine crosses him, the frequency of the sound heard by him changes by a factor f. The actual difference in the frequencies of the sound heard by him before and after the engine crosses him is
(A) $\frac{1}{2}n_0(1 - f^2)$ (B) $\frac{1}{2}n_0\left(\frac{1-f^2}{f}\right)$ (C) $n_0\left(\frac{1-f}{1+f}\right)$ (D) $\frac{1}{2}n_0\left(\frac{1-f}{1+f}\right)$

Q.54 A closed organ pipe of length 1.2 m vibrates in its first overtone mode. The pressure variation is maximum at:
(A) 0.8 m from the open end
(B) 0.4 m from the open end
(C) at the open end
(D) 1.0 m from the open end

Q.55 The figure shows four progressive waves A, B, C & D. It can be concluded from the figure that with respect to wave A :

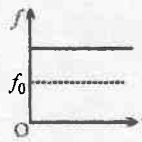


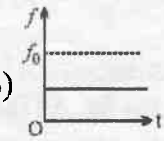
(A) the wave C is ahead by a phase angle of $\pi/2$ & the wave B lags behind by a phase angle $\pi/2$
(B) the wave C lags behind by a phase angle of $\pi/2$ & the wave B is ahead by a phase angle of $\pi/2$
(C) the wave C is ahead by a phase angle of π & the wave B lags behind by the phase angle of π
(D) the wave D lags behind by a phase angle of π & the wave B is ahead by a phase angle of π.

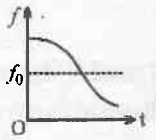
Q.56 The resultant amplitude due to superposition of two waves $y_1 = 5\sin(wt - kx)$ and $y_2 = -5\cos(wt - kx - 150°)$
(A) 5
(B) $5\sqrt{3}$
(C) $5\sqrt{2-\sqrt{3}}$
(D) $5\sqrt{2+\sqrt{3}}$

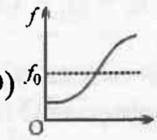
Q.57 A closed organ pipe and an open pipe of same length produce 4 beats when they are set into vibrations simultaneously. If the length of each of them were twice their initial lengths, the number of beats produced will be
(A) 2
(B) 4
(C) 1
(D) 8

Q.58 Source and observer both start moving simultaneously from origin, one along x-axis and the other along y-axis with speed of source = twice the speed of observer. The graph between the apparent frequency observed by observer f and time t would approximately be :

(A) 

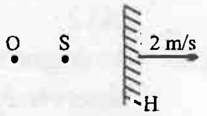
(B) 

(C) 

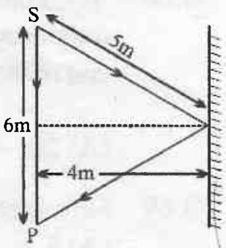
(D) 

Q.59 A closed organ pipe of radius r_1 and an organ pipe of radius r_2 and having same length 'L' resonate when excited with a given tunning fork. Closed organ pipe resonates in its fundamental mode where as open organ pipe resonates in its first overtone, then
(A) $r_2 - r_1 = L$
(B) $r_2 - r_1 = L/2$
(C) $r_2 - 2r_1 = 2.5\ L$
(D) $2r_2 - r_1 = 2.5\ L$

Q.60 A stationary sound source 's' of frequency 334 Hz and a stationary observer 'O' are placed near a reflecting surface moving away from the source with velocity 2 m/sec as shown in the figure. If the velocity of the sound waves is air is V = 330 m/sec, the apparent frequency of the echo is
(A) 332 Hz
(B) 326 Hz
(C) 334 Hz
(D) 330 Hz



Q.61 A person standing at a distance of 6 m from a source of sound receives sound wave in two ways, one directly from the source and other after reflection from a rigid boundary as shown in the figure. The maximum wavelength for which, the person will receive maximum sound intensity, is



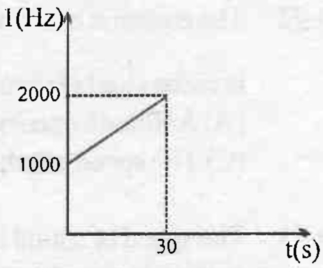
(A) 4 m (B) $\frac{16}{3}$ m (C) 2 m (D) $\frac{8}{3}$ m

Q.62 A listender is at rest w.r.t. the source of sound. A wind starts blowing along the line joining the source and the observer. Then
(A) frequency and wavelength will not change.
(B) frequency and velocity of sound will not change.
(C) frequency and time period will not change.
(D) frequency, time period and wavelength will not change.

Q.63 A source S of frequency f_0 and an observer O, moving with speeds v_1 and v_2 respectively, are movinng away from each other. When they are separated by distance a (t =0), a pulse is emitted by the source. This pulse is received by O at time t_1 then t_1 is equal to

(A) $\frac{a}{v_s + v_2}$ (B) $\frac{a}{v_1 + v_s}$ (C) $\frac{a}{v_s - v_2}$ (D) $\frac{a}{v_1 + v_2 + v_s}$

Q.64 A detector is released from rest over a source of sound of frequency $f_0 = 10^3$ Hz. The frequency observed by the detector at time t is plotted in the graph. The speed of sound in air is ($g = 10\ m/s^2$)



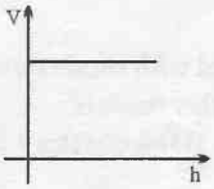
(A) 330 m/s (B) 350 m/s
(C) 300 m/s (D) 310 m/s

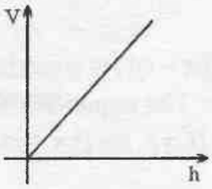
Q.65 The frequency of a sonometer wire is f, but when the weights producing the tensions are completely immersed in water the frequency becomes f/2 and on immersing the weights in a certain liquid the frequency becomes f/3. The specific gravity of the liquid is:

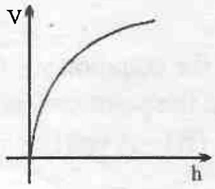
(A) $\frac{4}{3}$ (B) $\frac{16}{9}$ (C) $\frac{15}{12}$ (D) $\frac{32}{27}$

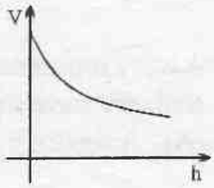
Q.66 First overtone frequency of a closed organ pipe is equal to the first overtone frequency of an open organ pipe. Further nth harmonic of closed organ pipe is also equal to the mth harmonic of open pipe, where n and m are:
(A) 5, 4 (B) 7. 5 (C) 9, 6 (D) 7, 3

Q.67 A uniform rope having some mass hanges vertically from a rigid support. A transverse wave pulse is produced at the lower end. The speed (v) of the wave pulse varies with height (h) from the lower end as:

(A) 

(B) 

(C) 

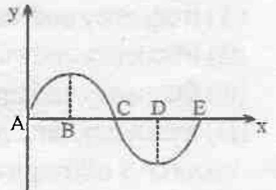
(D) 

Q.68 If l_1 and l_2 are the lengths of air column for the first and second resonance when a tuning fork of frequency n is sounded on a resonance tube, then the distance of the displacement antinode from the top end of the resonance tube is:

(A) $2(l_2 - l_1)$ (B) $\frac{1}{2}(2l_1 - l_2)$ (C) $\frac{l_2 - 3l_1}{2}$ (D) $\frac{l_2 - l_1}{2}$

Q.69 How many times more intense is 90 dB sound than 40 dB sound?
(A) 5 (B) 50 (C) 500 (D) 10^5

Q.70 Sound wave is travelling along positive x-direction. Displacement (y) of particles at any time t is as shown in figure. Select the wrong statement:



(A) Particle located at E has its velocity in negative x-direction
(B) Particle located at D has zero velocity
(C) Particles located between B and C are under compression
(D) None of the above

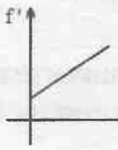
Q.71 The ratio of intensities between two coherent soud sources is 4 : 1. The differenmce of loudness in dB between maximum and minimum intensities when they interfere in space is:
(A) 10 log 2 (B) 20 log 3 (C) 10 log 3 (D) 20 log 2

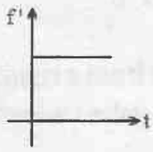
Q.72 The equation of a wave disturbance is given as : $y = 0.02 \cos\left(\frac{\pi}{2} + 50\pi t\right) \cos(10\pi x)$, where x and y are in meters and t in seconds. Choose the wrong statement:
(A) Antinode occurs at x = 0.3 m (B) The wavelength is 0.2 m
(C) The speed of teh constituent waves is 4 m/s (D) Node occurs at x = 0.15 m

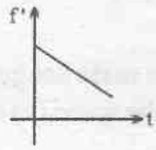
Q.73 The speed of sound in a gas, in which two waves of wavelength 1.0 m and 1.02 m produce 6 beats per second, is approximately:
(A) 350 m/s (B) 300 m/s (C) 380 m/s (D) 410 m/s

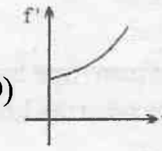
Q.74 For a certain organ pipe three successive resonance frequencies are observed at 425 Hz, 595 Hz and 765 Hz respectively. If the speed of sound in air is 340 m/s, then the length of the pipe is:
(A) 2.0 m (B) 0.4 m (C) 1.0 m (D) 0.2 m

Q.75 An observer starts moving with uniform acceleration 'a' towards a stationary sound source of frequency f. As the observer approaches the source, the apparent frequency f' heard by the observer varies with time t as:

(A) 

(B) 

(C) 

(D) 

Q.76 A wave represented by the equation $y = A\cos(kx - \omega t)$ is superimposed with another wave to form a statioary wave such that the point x =0 is a node. The equation of the other wave is:
(A) $-A\sin(kx + \omega t)$ (B) $-A\cos(kx + \omega t)$ (C) $A\sin(kx + \omega t)$ (D) $A\cos(kx + \omega t)$

ANSWER KEY

Q.1	B	Q.2	A	Q.3	C	Q.4	D
Q.5	C	Q.6	A	Q.7	C	Q.8	A
Q.9	C	Q.10	C, D	Q.11	C, D	Q.12	D
Q.13	B, C	Q.14	B	Q.15	B	Q.16	C
Q.17	B	Q.18	A	Q.19	B, C	Q.20	A
Q.21	A	Q.22	D	Q.23	C	Q.24	B
Q.25	C	Q.26	B	Q.27	C	Q.28	B
Q.29	B, D	Q.30	B, D	Q.31	C	Q.32	B
Q.33	B	Q.34	A	Q.35	B	Q.36	D
Q.37	D	Q.38	A, B	Q.39	B, D	Q.40	B
Q.41	C, D	Q.42	C	Q.43	A, D	Q.44	B, D
Q.45	A	Q.46	A, B, D	Q.47	A, B, C, D	Q.48	A, C
Q.49	D	Q.50	C	Q.51	C	Q.52	C
Q.53	B	Q.54	B	Q.55	B	Q.56	A
Q.57	A	Q.58	B	Q.59	C	Q.60	D
Q.61	A	Q.62	C	Q.63	C	Q.64	C
Q.65	D	Q.66	C	Q.67	C	Q.68	C
Q.69	D	Q.70	D	Q.71	B	Q.72	C
Q.73	B	Q.74	C	Q.75	A	Q.76	B

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (PQRS & J)

MECHANICAL WAVES

CONTENTS

1. **Wave Equation :**

(i) The equation for a progressive wave travelling in the positive x-direction is

$$y = \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right),$$

where y is the displacemnet at point x, at time t, A is the amplitude, T is the period and λ is the wavelength.

The frequency is $\frac{1}{T}$ and the velocity of the wave is $\frac{\lambda}{T}$.

(ii) The equation for a stationary wave is

$$y = \left(2A\cos\frac{2\pi x}{\lambda}\right)\sin\frac{2\pi t}{T}$$

(iii) Pitch, loudness and quality are the characteristics of a musical note. Pitch depends on the frequency. Loudness depends on intensity and quality depends on the waveform of the constituent overtones.

(iv) Resonance occurs when the forcing frequency is equal to the natural frequency of a vibrating body.

(v) Velocity of propagation of sound in a gas = $\sqrt{\frac{\gamma P}{D}}$, where D is the density of the gas and γ is the ratio of specific heats.

2. **Vibrating air columns :**

(i) In a pipe of length L closed at one end, the funamental note has a frequency $f_1 = \frac{v}{4L}$, where v is the velocity of sound in air.

(ii) The first overtone $f_2 = \frac{v}{L} = 2f_1$

3. **Propagation of sound in solids :**

(i) The velocity of propagation of a longitudinal wave in a rod of Young's modulus Y and density ρ is given by

$$v = \sqrt{\frac{Y}{\rho}}$$

(ii) The velocity of propagation of a transverse wave in a streched string

$$v = \sqrt{\frac{T}{m}}$$

where T is the tension in the string and m is the mass per unit length of the string.

(iii) In a sonometer wire of length L and mass per unit length m under tension T vibrating in n loops

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{m}}$$

(iv) Propagation of sound in gases

Laplace formula $v = \sqrt{\frac{\gamma P}{\rho}}$

where γ is the ratio of specific heats, P is the pressure and ρ is the density.

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273+t}{273}}$$

4. **Doppler Effects :**

(i) When a source of sound moves with a velocity v_s in a certain direction, the wavelength decreases in front of the source and increases behind the source.

$$\lambda'\text{ (in front)} = \frac{v - v_s}{f_s}\ ;\ f' = \frac{v}{\lambda'} = \frac{v}{v - v_s} f_s$$

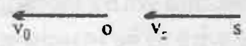
$$\lambda''\text{(behind)} = \frac{v + v_s}{f_s}\ ;\ f'' = \frac{v}{\lambda''} = \frac{v}{v + v_s} f_s$$

Here v is the velocity of sound in air.

(ii) The apparent frequency $= \frac{v - v_0}{v} f_s$

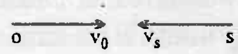
(a) When the source is moving towards the observer and the observer is moving away from the source, the apparent frequency

$$f_a = \frac{v - v_0}{v - v_s} f_s$$



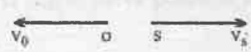
(b) When the source and the observer are moving towards each other.

$$f_a = \frac{v + v_0}{v - v_s} f_s$$



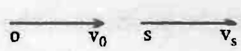
(c) When the source and observer are moving away from each other,

$$f_a = \frac{v - v_0}{v + v_s} f_s$$



(d) When the source is moving away from the observer and the observer is moving towards the source

$$f_a = \frac{v + v_0}{v + v_s} f_s$$



Here all velocities are relation to the medium.

5. **Loudness of sound :**

The loudness level B of sound is expressed in decibels,

$$B = 10 \log \frac{I}{I_0}$$

where I is the intensity, I_0 is a reference intensity.

6. **Beats :**

When two tuning forks of close but different frequencies f_1 and f_2 are vibrating simultaneously at nearby places, a listener observes a fluctuation in the intensity of sound, called beats. The number of beats heard per second is $f_1 - f_2$.

EXERCISE–I

Q.1 Two stationary sources A and B are sounding notes of frequency 680 Hz. An observer moves from A to B with a constant velocity u. If the speed of sound is 340 ms^{-1}, what must be the value of u so that he hears 10 beats per second?

Q.2 Find the intensity of sound wave whose frequency is 250 Hz. The displacement amplitude of particles of the medium at this position is 1×10^{-8} m. The density of the medium is 1 kg/m^3, bulk modulus of elasticity of the medium is 400 N/m^2.

Q.3 Two strings A and B with $\mu = 2$ kg/m and $\mu = 8$ kg/m respectively are joined in series and kept on a horizontal table with both the ends fixed. The tension in the string is 200 N. If a pulse of amplitude 1 cm travels in A towards the junction, then find the amplitude of reflected and transmitted pulse.

Q.4 A parabolic pulse given by equation y (in cm) = $0.3 - 0.1(x - 5t)^2$ $(y \geq 0)$ x in meter and t in second travelling in a uniform string. The pulse passes through a boundary beyond which its velocity becomes 2.5 m/s. What will be the amplitude of pulse in this medium after transmission?

Q.5 A car moving towards a vertical wall sounds a horn. The driver hears that the sound of the horn reflected from the cliff has a pitch half-octave higher than the actual sound. Find the ratio of the velocity of the car and the velocity of sound.

Q.6 The first overtone of a pipe closed at one end resonates with the third harmonic of a string fixed at its ends. The ratio of the speed of sound to the speed of transverse wave travelling on the string is 2 : 1. Find the ratio of the length of pipe to the length of string.

Q.7 A stretched uniform wire of a sonometer between two fixed knife edges, when vibrates in its second harmonic gives 1 beat per second with a vibrating tuning fork of frequency 200 Hz. Find the percentage change in the tension of the wire to be in unison with the tuning fork.

Q.8 A train blowing its whistle moves with a constant velocity v away from an observer on the ground. The ratio of the natural frequency of the whistle to that measured by the observer is found to be 1.2. If the train is at rest and the observer moves away from it at the same velocity, then find the ratio.

Q.9 Tuning fork A when sounded with a tuning fork B of frequency 480 Hz gives 5 beats per second. When the prongs of A are loaded with wax, it gives 3 beats per second. Find the original frequency of A.

Q.10 A sound wave of frequency f propagating through air with a velocity C, is reflected from a surface whi h is moving away from the fixed source with a constant speed n . Find the frequency of the reflected wave, measured by the observer at the position of the source.

Q.11 The loudness level at a distance R from a long linear source of sound is found to be 40dB. At this point, the amplitude of oscillations of air molecules is 0.01 cm. Then find the loudness level & amplitude at a point located at a distance '10R' from the source.

Q.12 A sonometer wires resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by M, the wire resonates with the same tuning fork forming three antinodes for the same position of bridges. Find the value of M.

Q.13 A car is moving towards a huge wall with a speed = c/10 , where c = speed of sound in still air. A wind is also blowing parallel to the velocity of the car in the same direction and with the same speed. If the car sounds a horn of frequency f, then what is the frequency of the reflected sound of the horn heared by driver of the car?

Q.14 A 40 cm long wire having a mass 3.2 gm and area of c.s. 1 mm^2 is stretched between the support 40.05 cm apart. In its fundamental mode. It vibrate with a frequency 1000/64 Hz. Find the young's modulus of the wire.

Q.15 A steel rod having a length of 1 m is fastened at its middle. Assuming young's modulus to be 2×10^{11} Pa. and density to be 8 gm/cm^3 find the fundamental frequency of the longitudinal vibration and frequency of first overtone.

Q.16 A sound source of small size produces a spherical sound wave with a frequency of 3 kHz in air. At a distance $r_1 = 100$ m from the source, the sound loudness level is $L_1 = 60$ dB. Find the sound loudness level at a distance of $r_2 = 200$ m dB and the distance at which the sound stops being heard km.

Q.17 Two identical sounds A and B reach a point in the same phase. The resultant sound is C. The loudness of C is n dB higher than the loudness of A. Find the value of n.

Q.18 Sound of wavelength λ passes through a Quincke's tube, which is adjusted to give a maximum intensity I_0. Find the distance through the sliding tube should be moved to give an intensity $I_0/2$.

Q.19 In a resonance-column experiment, a long tube, open at the top, is clamped vertically. By a separate device, water level inside the tube can be moved up or down. The section of the tube from the open end to the water level act as a closed organ pipe. A vibrating tuning fork is held above the open end, and the second resonances occur when the water level is 24.1 cm and 74.1 cm repsectively below the open end. Find the diameter of the tube. [Hint : end correction is 0.3 d]

Q.20 In a mixture of gases, the average number of degrees of freedom per molecule is 6. The rms speed of the molecules of the gas is c. Find the velocity of sound in the gas.

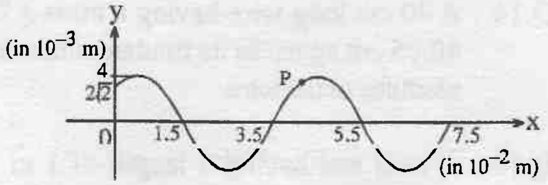
Q.21 A sonometer wire of length 114 cm is stretched between two fixed points. Two bridges, that should be mounted to divide the wire into three segments, such that their fundamental frequencies are in the ratio 1 : 3 : 4 must be mounted at distance ______ and ______ from one fixed end of the wire.

Q.22 A fixed source of sound emitting a certain frequency appears as f_a when the observer is approaching the source with speed v and frequency f_r when the observer recedes from the source with the same speed. Find the frequency of the source.

Q.23 A, B and C are three tuning forks. Frequency of A is 350Hz. Beats produced by A and B are 5 per second and by B and C are 4 per second. When a wax is put on A beat frequency between A and B is 2Hz and between A and C is 6Hz. Then, find the frequency of B and C respectively.

EXERCISE–II

Q.1 The figure shows a snap photograph of a vibrating string at t = 0. The particle P is observed moving up with velocity 20π cm/s. The angle made by string with x-axis at P is 6°.



(a) Find the direction in which the wave is moving

(b) the equation of the wave

(c) the total energy carried by the wave per cycle of the string, assuming that μ, the mass per unit length of the string = 50 gm/m.

Q.2 A uniform rope of length L and mass m is held at one end and whirled in a horizontal circle with angular velocity ω. Ignore gravity. Find the time required for a transverse wave to travel from one end of the rope to the other.

Q.3 A symmetrical triangular pulse of maximum height 0.4 m and total length 1 m is moving in the positive x-direction on a string on which the wave speed is 24 m/s. At t = 0 the pulse is entirely located between x = 0 and x = 1 m. Draw a graph of the transverse velocity of particle of string versus time at x = +1m.

Q.4 A uniform string 240 cm long maintains a standing wave, with the points on the string at which displacements of the amplitude equalling $3\sqrt{2}$ mm occur at 20 cm interval along the length of the string. Find :

(a) the order of the overtone which these oscillations represent

(b) the maximum amplitude on the wire.

Q.5 A steel wire 8×10^{-4} m in diameter is fixed to a support at one end and is wrapped round a cylindrical tuning peg 5 mm in diameter at the other end. The length of the wire between the peg and the support is 0.06 m. The wire is initially kept taut but without any tension. What will be the fundamental frequency of vibration of the wire if it is tightened by giving the peg a quarter of a turn?
Density of steel = 7800 kg/m^3, Y of steel = 20×10^{10} N/m^2.

Q.6 The displacement of the medium in a sound wave is given by the equation ; $y_1 = A\cos(ax + bt)$ where A, a & b are positive constants. The wave is reflected by an obstacle situated at x = 0. The intensity of the reflected wave is 0.64 times that of the incident wave.

(a) what are the wavelength & frequency of the incident wave.

(b) write the equation for the reflected wave.

(c) in the resultant wave formed after reflection, find the maximum & minimum values of the particle speeds in the medium.

Q.7 The harmonic wave $y_i = (2.0 \times 10^{-3}) \cos\pi (2.0x - 50t)$ travels along a string toward a boundary at x = 0 with a second string. The wave speed on the second string is 50 m/s. Write expresions for reflected and transmitted waves. Assume SI units.

Q.8 In a stationary wave pattern that forms as a result of reflection of waves from an obstacle the ratio of the amplitude at an antinode and a node is β=1.5. What percentage of the energy passes across the obstacle?

Q.9(a) A standing wave in second overtone is maintained in a open organ pipe of length *l*. The distance between consecutive displacement node and pressure node is ________.

(b) Two consecutive overtones produced by a narrow air column closed at one end and open at the other are 750Hz and 1050Hz. Then the fundamental frequency from the column is ______.

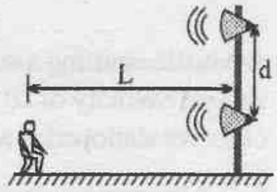
(c) A standing wave of frequency 1100Hz in a column of methane at 20^{0}C produces nodes that are 20 cm apart. What is the ratio of the heat capacity at constant pressure to that at constant volume.

Q.10 An open organ pipe filled with air has a fundamental frequency 500Hz. The first harmonic of another organ pipe closed at one end and filled with carbon dioxide has the same frequency as that of the first harmonic of the open organ pipe. Calculate the length of each pipe. Assume that the velocity of sound in air and in carbondioxide to be 330 and 264 m/s respectively.

Q.11 A string, 25cm long, having a mass of 0.25 gm/cm, is under tension. A pipe closed at one end is 40cm long. When the string is set vibrating in its first overtone, and the air in the pipe in its fundamental frequency, 8 beats/sec are heard. It is observed that decreasing the tension in the string, decreases the beat frequency. If the speed of sound in air is 320 m/s, find the tension in the string.

Q.12 A metal rod of length l = 100 cm is clamped at two points. Distance of each clamp from nearer end is a=30cm. If density and Young's modulus of elasticity of rod material are $\rho = 9000\ kg\ m^{-3}$ and Y = 144 GPa respectively, calculate minimum and next higher frequency of natural longitudinal oscillations of the rod.

Q.13 Two speakers are driven by the same oscillator with frequency of 200 Hz. They are located 4 m apart on a vertical pole. A man walks straight towards the lower speaker in a direction perpendicular to the pole, as shown in figure.

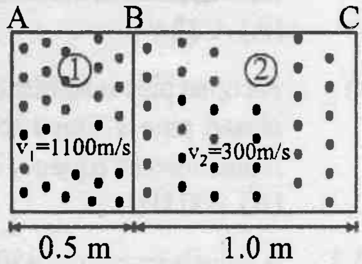


(a) How many times will he hear a minimum in sound intensity, and

(b) how far is he from the pole at these moments?

Take the speed of sound to be 330 m/s, and ignore any sound reflections coming off the ground.

Q.14 A cylinder ABC consists of two chambers 1 and 2 which contains two different gases. The wall C is rigid but the walls A and B are thin diaphragms. A vibrating tuning fork approaches the wall A with velocity u = 30 m/s and air columns in chamber 1 and 2 vibrates with minimum frequency such that there is node (displacement) at B and antinode (displacement) at A. Find



(i) the fundamental frequency of air column.

(ii) Find the frequency of tuning fork.

Assume velocity of sound in the first and second chamber be 1100 m/s and 300 m/s respectively. Velocity of sound in air 330 m/s.

Q.15 A source emits sound waves of frequency 1000 Hz. The source moves to the right with a speed of 32 m/s relative to ground. On the right a reflecting surface moves towards left with a speed of 64 m/s relative to the ground. The speed of sound in air is 332 m/s. Find

(a) the wavelength of sound in air by source

(b) the number of waves arriving per second which meet the reflecting surface.

(c) the speed of reflected waves.

(d) the wavelength of reflected waves.

Q.16 A supersonic jet plane moves parallel to the ground at speed v = 0.75 mach (1 mach = speed of sound). The frequency of its engine sound is $\nu_0 = 2$ kHz and the height of the jat plane is h = 1.5 km. At some instant an observer on the ground hears a sound of frequency $\nu = 2\nu_0$. Find the instant prior to the instant of hearing when the sound wave received by the observer was emitted by the jet plane. Velocity of sound wave in the condition of observer = 340 m/s.

Q.17 A train of length l is moving with a constant speed v along a circular track of radius R, The engine of the train emits a whistle of frequency f. Find the frequency heard by a guard at the rear end of the train.

Q.18 A bullet travels horizontally at 660 m/s at a height of 5 m from a man. How far is the bullet from the man when he hears its whistle? Velocity of sound in air = 340 m/s.

EXERCISE–III

Q.1 A metallic rod of length 1 m is rigidly clamped at its mid–point. Longitudinal stationary waves are set up in the rod in such a way that there are two nodes on either side of the mid–point. The amplitude of an antinode is 2×10^{-6}m. Write the equation of motion at a point 2 cm from the mid-point and those of the constituent waves in the rod. [Young's modulus = 2×10^{11} Nm^{-2}, density = 8000 Kg m^{-3}].
[JEE '94, 6]

Q.2 A whistle emitting a sound of frequency 440 Hz is tied to a string of 1.5 m length and rotated with an angular velocity of 20 rad s^{-1} in the horizontal plane. Calculate the range of frequencies heard by an observer stationed at a large distance from the whistle. [JEE '96, 3]

Q.3 Select the correct alternative : [JEE '96, 2 × 2 = 4]

(i) The extension in a string, obeying Hooke's law is x. The speed of wave in the stretched string is v. If the extension in the string is increased to 1.5 x, the speed of wave will be
(A) 1.22 v (B) 0.61 v (C) 1.50 v (D) 0.75 v

(ii) An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz than the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is :
(A) 200 Hz (B) 300 Hz (C) 240 Hz (D) 480 Hz

Q.4 A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer in Hz is : [JEE '97, 1]
(A) 409 (B) 429 (C) 517 (D) 500

Q.5 The first overtone of an open organ pipe beats with the first overtone of a closed organ pipe with a beat frequency of 2.2 Hz. The fundamental frequency of the closed organ pipe is 110 Hz. Find the lengths of the pipes. [JEE '97, 5]

Q.6 A place progressive wave of frequency 25 Hz, amplitude 2.5×10^{-5} m & initial phase zero propagates along the (–ve) x–direction with a velocity of 300 m/s. At any instant, the phase difference between the oscillations at two points 6 m apart along the line of propagation is ____ & the corresponding amplitude difference is ____ m. [JEE '97, 2]

Q.7 A band playing music at a frequency *f* is moving towards a wall at a speed v_b. A motorist is following the band with a speed v_m. If v is the speed of sound, obtain an expression for the beat frequency hear. by the motorist. [JEE '97, 5]

Q.8 A travelling in a stretched string is described by the equation $y = A\sin(kx - \omega t)$. The maximum particle velocity is : [JEE '97, 1]
(A) $A\omega$ (B) ω/k (C) $d\omega/dk$ (D) x/t

Q.9 Select the correct alternative(s). [JEE '98, 2 + 2 + 2]

(i) The (x, y) co–ordinates of the corners of a square plate are (0, 0) (L, 0) (L, L) & (0, L). The edges of the plate are clamped & transverse standing waves are set up in it. If u (x, y) denotes t he displacement of the plate at the point (x, y) at some instant of time, the possible expression(s) for u is/are : (a = positive constant)

(A) $a\cos\left(\frac{\pi x}{2L}\right)\cos\left(\frac{\pi y}{2L}\right)$ (B) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$

(C) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{2\pi y}{L}\right)$ (D) $a\cos\left(\frac{2\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$

(ii) A string of length 0.4 m & mass 10^{-2} kg is tightly clamped at its ends. The tension in the string is 1.6 N. Identical wave pulses are produced at one end at equal intervals of time, Δt. The minimum value of Δt which allows constructive interference between successive pulses is :
(A) 0.05 s (B) 0.10 s (C) 0.20 s (D) 0.40 s

(iii) A transverse sinusoidal wave of amplitude a, wavelength λ & frequency f is travelling on a stretched string. The maximum speed of any point on the string is $\frac{v}{10}$, where v is speed of propagation of the wave. If $a = 10^{-3}$ m and $v = 10\ ms^{-1}$, then λ & f are given by :
(A) $\lambda = 2\pi \times 10^{-2}$ m (B) $\lambda = 10^{-2}$ m (C) $f = \frac{10^3}{2\pi}$ Hz (D) $f = 10^4$ Hz

Q.10 The air column in a pipe closed at one end is made to vibrate in its second overtone by a tuning fork of frequency 440 Hz. The speed of sound in air is 330 ms^{-1}. End corrections may be neglected. Let P_0 denote the mean pressure at any point in the pipe & ΔP_0 the maximum amplitude of pressure variation.
(i) Find the length L of the air column. [JEE '98, 2 + 2 + 2 + 2]
(ii) What is the amplitude of pressure variation at the middle of the column ?
(iii) What are the maximum & minimum pressures at the open end of the pipe.
(iv) What are the maximum & minimum pressures at the closed end of the pipe ?

Q.11 In hydrogen spectrum the wvaelength of H_α line is 656 nm, whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 nm. Estimated speed of the galaxy with respect to earth is, [JEE '99, 2]
(A) 2×10^8 m/s (B) 2×10^7 m/s (C) 2×10^6 m/s (D) 2×10^5 m/s

Q.12 A long wire PQR is made by joining two wires PQ and QR of equal radii. PQ has length 4.8 m and mass 0.06 kg. QR has length 2.56 m and mass 0.2kg. The wire PQR is under a tension of 80N. A sinusoidal wave-pulse of amplitude 3.5cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave-pulse. Calculate
(a) the time taken by the wave-pulse to reach the other end R of the wire, and
(b) the amplitude of the reflected and transmitted wave-pulses after the incident wave-pulse crosses the joint Q. [JEE '99, 4 + 6]

Q.13 As a wave progagates :
(A) the wave intensity remains constant for a plane wave
(B) the wave intensity decreases as the inverse of the distance from the source for a spherical wave
(C) the wave intensity decreases as the inverse square of the distance from the source for a spherical Wave
(D) total power of the sherical wave over the spherical survace centered at the source remains constant at all times. [JEE '99, 3]

Q.14 $y(x, t) = 0.8/[(4x + 5t)^2 + 5]$ represents a moving pulse, where x & y are in meter and t in second. Then:
(A) pulse is moving in +x direction (B) in 2 s it will travel a distance of 2.5 m
(C) its maximum displacement is 0.16 m (D) it is a symmetric pulse. [JEE '99, 3]

Q.15 In a wave motion $y = a \sin(kx - \omega t)$, y can represent :
(A) electric field (B) magnetic field (C) displacement (D) pressure [JEE '99, 3]

Q.16 Standing waves can be produced : [JEE '99, 3]
(A) on a string clamped at both the ends
(B) on a string clamped at one end and free at the other
(C) when incident wave gets reflected from a wall
(D) when two identical waves with a phase difference of p are moving in same direction

Q.17 A train moves towards a stationary observer with speed 34m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the train's speed is reduced to 17m/s, the frequency registered is f_2. If the speed of sound is 340m/s then the ratio f_1/f_2 is [JEE 2000 (Scr), 1]
(A) 18/19 (B) 1/2 (C) 2 (D) 19/18

Q.18 Two monatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate container kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by

(A) $\sqrt{\frac{m_1}{m_2}}$ (B) $\sqrt{\frac{m_2}{m_1}}$ (C) $\frac{m_1}{m_2}$ (D) $\frac{m_2}{m_1}$ [JEE 2000 (Scr)]

Q.19 Two vibrating strings of the same material but lengths L and 2L have radii 2r and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, the one of length L with frequency f_1 and the other with frequency f_2. The ratio f_1/f_2 is given by

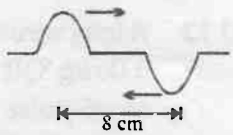
(A) 2 (B) 4 (C) 8 (D) 1 [JEE 2000 (Scr), 1]

Q.20 A 3.6 m long vertical pipe resonates with a source of frequency 212.5 Hz when water level is at certain heights in the pipe. Find the heights of water level (from the bottom of the pipe) at which resonances occur. Neglect end correction. Now, the pipe is filled to a height H (~ 3.6 m). A small hole is drilled very close to its bottom and water is allowed to leak. Obtain an expression for the rate of fall of water level in the pipe as a function of H. If the radii of the pipe and the hole are 2×10^{-2} m and 1×10^{-3} m respectively, calculate the time interval between the occurence of first two resonances. Speed of sound in air is 340 m/s and $g = 10$ m/s^2. [JEE 2000, 10]

Q.21 The ends of a stretched wire of length L are fixed at x = 0 and x = L. In one experiment, the displacement of the wire is $y_1 = A \sin(\pi x/L) \sin \omega t$ and energy is E_1 and in another experiment its displacement is $y_2 = A\sin(2\pi x/L) \sin 2\omega t$ and energy is E_2. Then [JEE 2001 (Scr)]

(A) $E_2 = E_1$ (B) $E_2 = 2E_1$ (C) $E_2 = 4E_1$ (D) $E_2 = 16E_1$

Q.22 Two pulses in a stretched string whose centres are initially 8 cm apart are moving towards each other as shown in figure. The speed of each pulse is 2 cm/s. After 2 seconds, the total energy of the pulses will be



(A) zero (B) purely kinetic
(C) purely potential (D) partly kinetic and partly potential

[JEE 2001 (Scr)]

Q.23 A boat is travelling in a river with a speed of 10 m/s along the stream flowing with a speed 2 m/s. From this boat, a sound transmitter is lowered into the river through a rigid support. The wavelength of the sound emitted from the transmitter inside the water is 14.45 mm. Assume that attenuation of sound in water and air is negligible.

(a) What will be the frequency detected by a receiver kept inside the river downstream ?

(b) The transmitter and the receiver are now pulled up into air. The air is blowing with a speed 5 m/sec in the direction opposite the river stream. Determine the frequency of the sound detected by the receiver. (Temperature of the air and water = 20°C ; Density of river water = 10^3 Kg/m^3; Bulk modulus of the water = 2.088×10^9 Pa; Gas constant R = 8.31 J/mol-K; Mean molecular mass of air = 28.8×10^{-3} kg/mol; C_P/C_V for air = 1.4) [JEE 2001, 5 + 5]

Q.24 A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz while the train approaches the siren. During his return journey in a different train B he records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that of train A is [JEE 2002 (Scr), 3]

(A) 242/252 (B) 2 (C) 5/6 (D) 11/6

Q.25 A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by a mass M, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of M is [JEE 2002 (Scr), 3]

(A) 25 kg (B) 5 kg (C) 12.5 kg (D) 1/25 kg

Q.26 Two narrow cylindrical pipes A and B have the same length. Pipe A is open at both ends and is filled with a monoatomic gas of malar mass M_A. Pipe B is open at one end and closed at the other end, and is filled with a diatomic gas of molar mass M_B. Both gases are at the same temperature.

(a) If the frequency of the second harmonic of the fundamental mode in pipe A is equal to the frequency of the third harmonic of the fundamental mode in pipe B, determine the value of M_A/M_B.

(b) Now the open end of pipe B is also closed (so that the pipe is closed at both ends). Find the ratio of the fundamental frequency in pipe A to that in pipe B. [JEE 2002, 3 + 2]

Q.27 A police van moving with velocity 22 m/s and emitting sound of frequency 176 Hz, follows a motor cycle in turn is moving towards a stationary car and away from the police van. The stationary car is emitting frequency 165 Hz. If motorcyclist does not hear any beats then his velocity is [JEE 2003 (Scr)]

(A) 22 m/s (B) 24 m/s (C) 20 m/s (D) 18 m/s

Q.28 A cylindrical tube when sounded with a tuning fork gives, first resonance when length of air column is 0.1 and gives second resonance when the length of air column is 0.35 m. Then end correction is

(A) 0.025 m (B) 0.020 m (C) 0.018 m (D) 0.012 m

[JEE 2003 (Scr)]

Q.29 A stringe between x = 0 and x = l vibrates in fundamental mode. The amplitude A, tension T and mass per unit length μ is given. Find the total energy of the string. [JEE 2003]



Q.30 A tuning fork of frequency 480 Hz resonates with a tube closed at one end of length, 16 cm and diameter 5 cm in fundamental mode. Calculate velocity of sound in air. [JEE 2003]

Q.31 A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open organ pipe is [JEE' 2004 (Scr)]

(A) $\frac{L}{3}$ (B) $\frac{4L}{3}$ (C) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (D) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

Q.32 A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500m/s and in air it is 300m/s. The frequency of sound recorded by an observer who is standing in air is

(A) 200 Hz (B) 3000 Hz (C) 120 Hz (D) 600 Hz [JEE' 2004 (Scr)]

Q.33 A string fixed at both ends is in resonance in its 2nd harmonic with a tuning fork of frequency f_1. Now its one end becomes free. If the frequency of the tuning fork is increased slowly from f_1 then again a resonance is obtained when the frequency is f_2. If in this case the string vibrates in nth harmonic then

(A) $n = 3, f_2 = \frac{3}{4} f_1$ (B) $n = 3, f_2 = \frac{5}{4} f_1$ (C) $n = 5, f_2 = \frac{5}{4} f_1$ (D) $n = 5, f_2 = \frac{3}{4} f_1$

[JEE' 2005 (Scr)]

Q.34 In a resonance column method, resonance occurs at two successive level of l_1=30.7 cm and l_2 = 63.2 cm using a tuning fork of f = 512 Hz. What is the maximum error in measuring speed of sound using relations $v = f\lambda$ & $\lambda = 2(l_2 - l_1)$

(A) 256 cm/sec (B) 92 cm/sec (C) 128 cm/sec (D) 102.4 cm/sec

[JEE' 2005 (Scr)]

Q.35 A whistling train approaches a junction. An observer standing at junction observers the frequency to be 2.2 KHz and 1.8 KHz of the approaching and the receding train. Find the speed of the train (speed sound = 300 m/s). [JEE 2005]

Q.36 A transverse harmonic disturbance is produced in a string. The maximum transverse velocity is 3 m/s and maximum transverse acceleration is 90 m/s^2. If the wave velocity is 20 m/s then find the waveform.

[JEE 2005]

ANSWER KEY

EXERCISE–I

Q.1 2.5 ms^{-1} Q.2 $\frac{\pi^2\times10^{-9}}{4}$ W/m² Q.3 $A_r = -\frac{1}{3}$ cm, $A_t = \frac{2}{3}$ cm Q.4 0.2 cm

Q.5 1 : 5 Q.6 1 : 1 Q.7 1% Q.8 1.25 Q.9 485 Hz

Q.10 $\frac{f(C-v)}{C+v}$ Q.11 30 dB, $10\sqrt{10}$ μm Q.12 25 kg Q.13 11f / 9

Q.14 1×10^{9} Nm² Q.15 2.5 kHz, 7.5 kHz

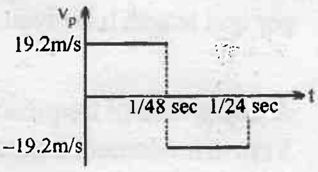
Q.16 54, 100 Q.17 6 Q.18 λ/8 Q.19 3 cm

Q.20 2c/3 Q.21 72, 96 or 18, 42 Q.22 $\frac{f_r+f_a}{2}$ Q.23 345, 341 or 349 Hz

EXERCISE–II

Q.1 (a) negative x ; (b) $y = 4\times10^{-3}\sin 100\pi\left(3t + 0.5x + \frac{\pi}{4}\right)$ (x , y in meter) ; (c) $72\pi^2\times10^{-5}$ J

Q.2 $\frac{\pi}{\sqrt{2}\omega}$ Q.3



Q.4 (a) 5, 11 (b) 6 mm ; $3\sqrt{2}$ mm Q.5 10800 Hz

Q.6 (a) 2 π/a, b/2π, (b) $y_2 = \pm 0.8\,A\cos(ax - bt)$, (c) max.=1.8 b A, min. = 0,

Q.7 (a) $6.67\times10^{-4}\cos\pi(2.0x + 50t)$; (b) $2.67\times10^{-3}\cos\pi(1.0x - 50t)$ SI units

Q.8 96 % Q.9 (a) l/6; (b) 150 Hz; (c)1.28 Q.10 33 cm and 13.2 cm

Q.11 67.6 N Q.12 10kHz, 30kHz Q.13 (a) 2 ; (b) 9.28 m and 1.99 m

Q.14 1650 Hz, 1500 Hz

Q.15 (a) 0.3 m, (b) 1320, (c) 332 m/s, (d) 0.2 m Q.16 5.9 sec Q.17 f Q.18 9.7 m

EXERCISE–III

Q.1 $y = 2\times10^{-6}\sin(0.1\pi)\cos(25000\pi t + \theta)$, for θ = 0 : $y_1 = 10^{-6}\sin(5\pi x - 25000\pi t)$, $y_2 = 10^{-6}\sin(5\pi x + 25000\pi t)$

Q.2 $f_{max} = 484$ Hz , $f_{min} = 403.3$ Hz Q.3 (i) A, (ii) A

Q.4 D Q.5 $L_c = 0.75$ m ; $L_o = 0.99$ m or 1.006 m Q.6 π rad, 0 m

Q.7 $\frac{2v_b(v+v_m)f}{v^2 - v_b^{\,2}}$ Q.8 A Q.9 (i) B, C (ii) B, (iii) A,C

Q.10 (i) $L = \frac{15}{16}$ m, (ii) $\frac{\Delta P_0}{\sqrt{2}}$, (iii) $P_{max} = P_{min} = P_0$, (iv) $P_{max} = P_0 + \Delta P_0$, $P_{min} = P_0 - \Delta P_0$ Q.11 B

Q.12 (a) Time = 140 ms, (b) $A_r = \frac{V_2 - V_1}{V_2 + V_1}A_i = 1.5$ cm ; $A_t = \frac{2V_2}{V_1 + V_2}A_i = 2$ cm

Q.13 A,C,D Q.14 B, C,D Q.15 A, B, C Q.16 A, B, C Q.17 D

Q.18 B Q.19 D Q.20 h = 3.2, 2.4, 1.6, 0.8, 0; $v = 5\times10^{-3}\sqrt{5H}$; $\Delta t = 80\,(4 - 2\sqrt{3})$

Q.21 C Q.22 B Q.23 (a) 100696 Hz (b) 103038 Hz Q.24 B Q.25 A

Q.26 (a) 2.116, (b) $\frac{3}{4}$ Q.27 A Q.28 A Q.29 $E = \frac{A^2\pi^2T}{4l}$ Q.30 336 m/s

Q.31 C Q.32 D Q.33 C Q.34 D Q.35 $V_s = 30$ m/s

Q.36 $y = (10\text{ cm})\sin\left(30t \pm \frac{3}{2}x + \phi\right)$

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

MODERN PHYSICS

QUESTION FOR SHORT ANSWER

ATOMIC PHYSICS

Q.1 In the photoelectric effect, why does the existence of a cutoff frequency speak in favour of the photon theory and against the wave theory?

Q.2 Explain the statement that one's eyes could not detect faint starlight if light were not particle-like.

Q.3 How can a photon energy be given by $E = hf$ when the very presence of the frequency f in the formula implies that light is a wave?

Q.4 The momentum p of a photon is given by $p = h/\lambda$. Why is it that c, the speed of light, does not appear in this expression?

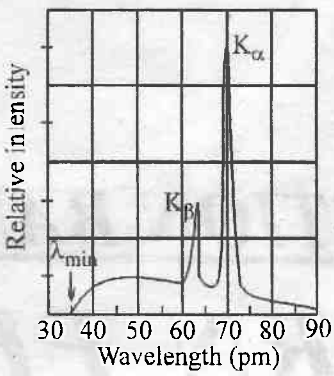
Q.5 Given that $E = hf$ for a photon, the Doppler shift in frequency of radiation from a receding light source would seem to indicate a reduced energy for the emitted photons. Is this in fact true? If so, what happened to the conservation of energy principle?

Q.6 Any series of atomic hydrogen yet to be observed will probably be found in what region of the spectrum?

Q.7 Can a hydrogen atom absorb a photon whose energy exceeds its binding energy(13.6 eV)?

Q.8 Only a relatively small number of Balmer lines can be observed from laboratory discharge tubes, whereas a large number are observed in stellar spectra. Explain this in terms of the small density, high temperature, and large volume of gases in stellar atmospheres.

Q.9 What is the origin of the cutoff wavelength λ_{min} of figure shown? Why is it an important clue to the photon nature of x rays?



Q.10 Can atomic hydrogen be caused to emit x rays? If so, describe how. If not, why not?

Q.11 Why is it that Bohr theory, which does not work very well even for helium (Z = 2), gives such a good account of the characteristic x-ray spectra of the elements, or at least of that portion that originates deep within the atom?

Q.12 The ionization potential of hydrogen is 13.6 V. Yet to obtain discharge in a cathode ray tube filled with hydrogen, a very high voltage (~10^4V) has to be applied across the tube. Explain this clearly. Also explain why the gas must be at low pressure to obtain discharge.

Q.13 X-rays are produced when a fast electron hits a proper target. What happens to the electron?

Q.14 Why does the tail of a comet always point away from the sun?

Q.15 A neutron pion at rest decays into two gamma photons.

$$\pi^0 \longrightarrow \gamma + \gamma$$

Why cannot a single photon be born? What conservation law is in contradiction with it?

Q.16 What is so special about e/m rather than e end m separately?

Q.17 Why is it advisable to view a TV screen from a distance of about ten feet?

Q.18 The electrical conductivity of a gas increases when X-rays or γ-rays pass through it. Explain this phenomenon.

Q.19 In photoelectric emission exchange of energy takes place among... (photon and electron/ photon, electron and lattice).

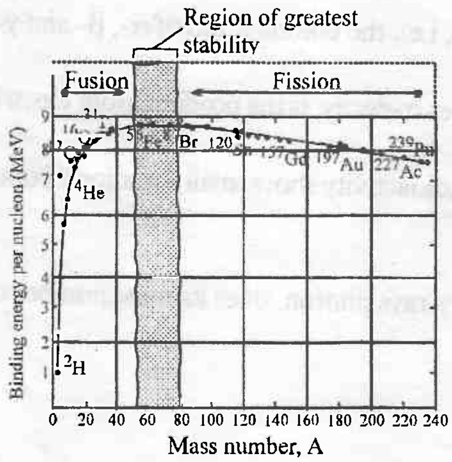
Q.20 The threshold frequencies for photoemission for three metals numbered 1,2,3 are respectively v_1, v_2, v_3 and $v_1 > v_2 > v_3$. An incident radiation of frequency $v_0 > v_2$ ... cause photoemission from 3 but... cause photoemission from 1 (fill in the gaps with may, may not / will certainly).

NUCLEAR PHYSICS

Q.1 Why does the relative importance of the Coulomb force compared to the strong nuclear force increase at large mass numbers?

Q.2 In your body, are there more neutrons than protons? More protons than electrons? Discuss

Q.3 Why is the binding energy per nucleon (see figure) low at low mass numbers? At high mass numbers?



Q.4 A radioactive nucleus can emit a positron, e^+. This corresponds to a proton in the nucleus being converted to a neutron. The mass of a neutron, however, is greater than that of a proton. How then can positron emission occur?

Q.5 In beta decay the emitted electrons form a continuous spectrum, but in alpha decay the alpha particles form a discrete spectrum. What difficulties did this cause in the explanation of beta decay, and how were these difficulties finally overcome?

Q.6 How do neutrinos differ from photons? Each has zero charge and (presumably) zero rest mass and travels at the speed of light.

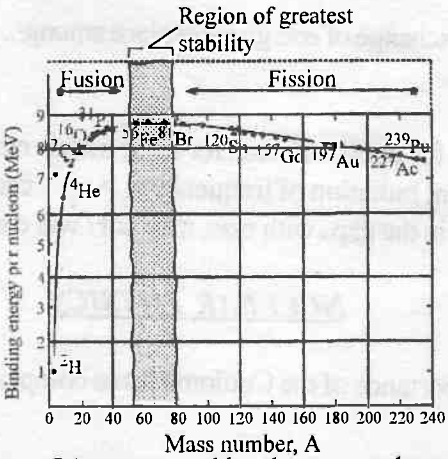
Q.7 In radioactive dating with ^{238}U, how do you get around the fact that you do not know how much ^{238}U was present in the rocks to begin with? (Hint: What is the ultimate decay product of ^{238}U?)

Q.8 If it is so much harder to get a nucleon out of a nucleus than to get an electron out of an atom, why try?

Q.9 In the generalized equation for the fission of ^{235}U by thermal neutrons, $^{235}U + n \rightarrow X + Y + bn$, do you expect the Q of the reaction to depend on the identity of X and Y?

Q.10 The half-life of ^{235}U is 7.0×10^8 y. Discuss the assertion that if it had turned out to be shorter by a factor of 10 or so, there would not be any atomic bombs today.

Q.11 The binding energy curve of figure tells us that any nucleus more massive than $A \approx 56$ can release energy by the fission process. Only very massive nuclides seem to do so, however. Why cannot lead, for example, release energy by the fission process?



Q.12 Elements up to mass number ≈ 56 are created by thermonuclear fusion in the cores of stars. Why are heavier elements not also created by this process?

Q.13 Which would generate more radioactive waste products :- a fission reactor or a fusion reactor?

Q.14 How can Becquerel rays, i.e., the combination of α-, β- and γ-rays, be separated?

Q.15 When a nucleus undergoes α-decay, is the product atom electrically neutral? In β-decay?

Q.16 Experimental results in radioactivity show small variations from the results predicted by theory. Explain this.

Q.17 If a nucleus emits only a γ-rays photon, does its mass number change? Does its mass change?

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

Q.1 Let n_r and n_b be respectively the number of photons emitted by a red bulb and a blue bulb of equal power in a given time.
(A) $n_r = n_b$ (B) $n_r < n_b$ (C) $n_r > n_b$ (D) data insufficient

Q.2 10^{-3} W of 5000 Å light is directed on a photoelectric cell. If the current in the cell is 0.16 μA, the percentage of incident photons which produce photoelectrons, is
(A) 0.4% (B) .04% (C) 20% (D) 10%

Q.3 A proton and an electron are accelerated by same potential difference have de-Broglie wavelength λ_p and λ_e.
(A) $\lambda_e = \lambda_p$ (B) $\lambda_e < \lambda_p$ (C) $\lambda_e > \lambda_p$ (D) none of these.

Q.4 Two electrons are moving with the same speed v. One electron enters a region of uniform electric field while the other enters a region of uniform magnetic field, then after sometime if the de-Broglie wavelengths of the two are λ_1 and λ_2, then:
(A) $\lambda_1 = \lambda_2$ (B) $\lambda_1 > \lambda_2$ (C) $\lambda_1 < \lambda_2$ (D) $\lambda_1 > \lambda_2$ or $\lambda_1 < \lambda_2$

Q.5 In a photo-emissive cell, with exciting wavelength λ, the maximum kinetic energy of electron is K. If the exciting wavelength is changed to $\frac{3\lambda}{4}$ the kinetic energy of the fastest emitted electron will be:
(A) 3K/4 (B) 4K/3 (C) less than 4K/3 (D) greater than 4K/3

Q.6 If the frequency of light in a photoelectric experiment is doubled, the stopping potential will
(A) be doubled (B) halved
(C) become more than doubled (D) become less than double

Q.7 An electron with initial kinetic energy of 100 eV is acceleration through a potential difference of 50 V. Now the de-Broglie wavelength of electron becomes
(A) 1 Å (B) $\sqrt{1.5}$ Å (C) $\sqrt{3}$ Å (D) 12.27 Å

Q.8 If h is Planck's constant is SI system, the momentum of a photon of wavelength 0.01 Å is:
(A) 10^{-2} h (B) h (C) 10^2 h (D) 10^{12} h

Q.9 The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect
(A) n = 3 to 1 (B) n = 3 to 2 (C) n = 2 to 1 (D) n = 4 to 1

Q.10 When a photon of light collides with a metal surface, number of electrons, (if any) coming out is
(A) only one (B) only two (C) infinite (D) depends upon factors

Q.11 Two radioactive material A_1 and A_2 have decay constants of $10\lambda_0$ and λ_0. If initially they have same number of nuclei, the ratio of number of their undecayed nuclei will be (1/e) after a time
(A) $\frac{1}{\lambda_0}$ (B) $\frac{1}{9\lambda_0}$ (C) $\frac{1}{10\lambda_0}$ (D) 1

Q.12 The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. This will :

(A) increase the maximum energy of the photoelectrons, as well as photoelectric current by a factor of two.

(B) increase the maximum kinetic energy of the photo electrons and would increase the photoelectric current by a factor of two.

(C) increase the maximum kinetic energy of the photoelectrons by a factor of greater than two and will have no effect on the magnitude of photoelectric current produced.

(D) not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two.

Q.13 Light coming from a discharge tube filled with hydrogen falls on the cathode of the photoelectric cell. The work function of the surface of cathode is 4eV Which one of the following values of the anode voltage (in Volts) with respect to the cathode will likely to make the photo current zero.

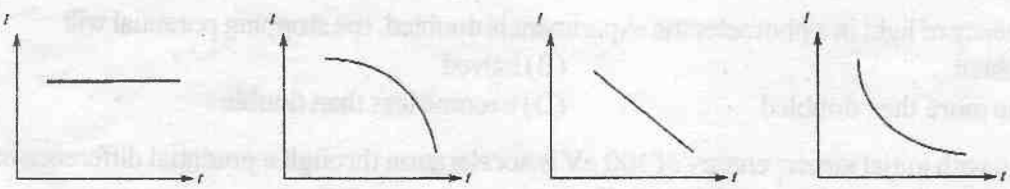
(A) – 4 (B) – 6 (C) – 8 (D) – 10

Q.14 A point source of ligth is used in a photoelectric effect. If the source is removed farther from the emitting metal, the stopping potential :

(A) will increase (B) will decrease

(C) will remain constant (D) will either increase or decrease.

Q.15 A point source causes photoelectric effect from a small metal plate. Which of the following curves may represent the saturation photocurrent as a function of the distance between the source and the metal ?

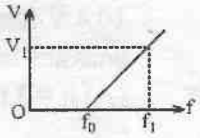


(A) (B) (C) (D)

Q.16 Let K_1 be the maximum kinetic energy of photoelectrons emitted by a light of wavelength λ_1 and K_2 corresponding to λ_2. If $\lambda_1 = 2\lambda_2$, then :

(A) $2K_1 = K_2$ (B) $K_1 = 2K_2$ (C) $K_1 < \frac{K_2}{2}$ (D) $K_1 > 2K_2$

Q.17 In a photoelectric experiment, the potential difference V that must be maintained between the illuminated surface and the collector so as just to prevent any electron from reaching the collector is determined for different frequencies f of the incident illumination. The graph obtained is shown.



The maximum kinetic energy of the electrons emitted at frequency f_1 is

(A) hf_1 (B) $\frac{V_1}{(f_1 - f_0)}$ (C) $h(f_1 - f_0)$ (D) $eV_1(f_1 - f_0)$

Q.18 Radiation of two photon energies twice and five times the work function of metal are incident sucessively on the metal surface. The ratio of the maximum velocity of photoelectrons emitted is the two cases will be

(A) 1 :2 (B) 2 . 1 (C) 1 : 4 (D) 4 : 1

Q.19 Cut off potentials for a metal in photoelectric effect for light of wavelength λ_1, λ_2 and λ_3 is found to be V_1, V_2 and V_3 volts if V_1, V_2 and V_3 are in Arithmetic Progression and λ_1, λ_2 and λ_3 will be:

(A) Arithmetic Progression (B) Geometric Progression

(C) Harmonic Progression (D) None

Q.20 Photons with energy 5 eV are incident on a cathode C, on a photoelectric cell. The maximum energy of the emitted photoelectrons is 2 eV. When photons of energy 6 eV are incident on C, no photoelectrons will reach the anode A if the stopping potential of A relative to C is

(A) 3 V (B) – 3V (C) – 1V (D) 4 V

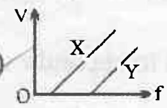
Q.21 In a photoelectric experiment, the collector plate is at 2.0V with respect to the emitter plate made of copper $\varphi = 4.5eV$). The emitter is illuminated by a source of monochromatic light of wavelength 200nm.

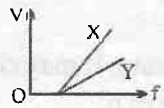
(A) the minimum kinetic energy of the photoelectrons reaching the collector is 0.
(B) the maximum kinetic energy of the photoelectrons reaching the collector is 3.7eV.
(C) if the polarity of the battery is reversed then answer to part A will be 0.
(D) if the polarity of the battery is reversed then answer to part B will be 1.7eV.

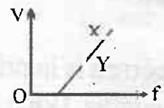
Q.22 By increasing the intensity of incident light keeping frequency $(v > v_0)$ fixed on the surface of metal

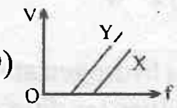
(A) kinetic energy of the photoelectrons increases
(B) number of emitted electrons increases
(C) kinetic energy and number of electrons increases
(D) no effect

Q.23 In a photoelectric experiment, electrons are ejected from metals X and Y by light of intensity I and frequency f. The potential difference V required to stop the electrons is measured for various frequencies. If Y has a greater work function than X ; which one of the following graphs best illustrates the expected results?

(A) 

(B) 

(C) 

(D) 

Q.24 Monochromatic light with a frequency well above the cutoff frequency is incident on the emitter in a photoelectric effect apparatus. The frequency of the light is then doubled while the intensity is kept constant. How does this affect the photoelectric current?

(A) The photoelectric current will increase.
(B) The photoelectric current will decrease.
(C) The photoelectric current will remain the same.
(D) None of these

Q.25 In a hypothetical system a particle of mass m and charge –3q is moving around a very heavy particle having cahrge q. Assuming Bohr's model to be true to this system, the orbital velocity of mass m when it is nearest to heavy particle is

(A) $\frac{3q^2}{2\varepsilon_0 h}$ (B) $\frac{3q^2}{4\varepsilon_0 h}$ (C) $\frac{3q}{2\varepsilon_0 h}$ (D) $\frac{3q}{4\varepsilon_0 h}$

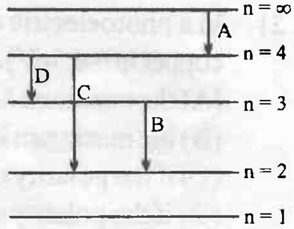
Q.26 de-Broglie wavelength of an electron in the nth Bohr orbit is λ_n and the angular momentum is J_n, then:

(A) $J_n \propto \lambda_n$ (B) $\lambda_n \propto \frac{1}{J_n}$ (C) $\lambda_n \propto J_n^2$ (D) none of these

Skip to Q51 and then complete Q27 – Q50 later
(only those marked E, btw)

Q.27 The angular momentum of an electron in the hydrogen atom is $\frac{3h}{2\pi}$. Here h is Planck's constant. The kinetic energy of this electron is:
(A) 4.53 eV (B) 1.51 eV (C) 3.4 eV (D) 6.8 eV

Q.28 Consider the following electronic energy level diagram of H-atom:
Photons associated with shortest and longest wavelengths would be emitted from the atom by the transitions labelled:



(A) D and C respectively
(B) C and A respectively
(C) C and D respectively
(D) A and C respectively

Q.29 In a hydrogen atom, the binding energy of the electron in the nth state is E_n, then the frquency of revolutionof the electron in the nth orbits is:
(A) $2E_n/nh$ (B) $2E_n n/h$ (C) E_n/nh (D) $E_n n/h$

Q.30 If the electron in a hydrogen atom were in the energy level with n = 3, how much energy in joule would be required to ionise the atom? (Ionisation energy of H-atom is 2.18×10^{-18}J):
(A) 6.54×10^{-19} (B) 1.43×10^{-19} (C) 2.42×10^{-19} (D) 3.14×10^{-20}

Q.31 In hydrogen and hydrogen like atoms, the ratio of difference of energies $E_{4n}-E_{2n}$ and $E_{2n}-E_n$ varies with its atomic number z and n as:
(A) z^2/n^2 (B) z^4/n^4 (C) z/n (D) $z^0 n^0$

Q.32 In a hydrogen atom, the electron is in nth excited state. It may come down to second excited state by emitting ten different wavelengths. What is the value of n:
(A) 6 (B) 7 (C) 8 (D) 5

Q.33 Difference between nth and (n+1)th Bohr's radius of 'H' atom is equal to it's (n−1)th Bohr's radius. the value of n is:
(A) 1 (B) 2 (C) 3 (D) 4

Q.34 An electron in hydrogen atom after absorbing energy photons can jump between energy states n_1 and $n_2(n_2 > n_1)$. Then it may return to ground state after emitting six different wavelengths in emission spectrum. the energy of emitted photons is either equal to, less than or greater than the absorbed photons. Then n_1 and n_2 are:
(A) $n_2 = 4, n_1 = 3$ (B) $n_2 = 5, n_1 = 3$ (C) $n_2 = 4, n_1 = 2$ (D) $n_2 = 4, n_1 = 1$

Q.35 The electron in a hydrogen atom makes transition from M shell to L. The ratio of magnitudes of initial to final centripetal acceleration of the electron is
(A) 9 : 4 (B) 81 : 16 (C) 4 : 9 (D) 16 : 81

Q.36 The electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$ whose n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The frequency of orbital motion of the electron in the initial state is 1/27 of that in the final state. The possible values of n_1 and n_2 are
(A) $n_1 = 4, n_2 = 2$ (B) $n_1 = 3, n_2 = 1$ (C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 6, n_2 = 3$

Q.37 The radius of Bohr's first orbit is a_0. The electron in nth orbit has a radius:
(A) na_0 (B) a_0/n (C) n^2a_0 (D) a_0/n^2

Q.38 The ionisation potential of hydrogen atom is 13.6 volt. The energy required to remove an electron from the second orbit of hydrogen is:
(A) 3.4 eV (B) 6.8 eV (C) 13.6 eV (D) 27.2 eV

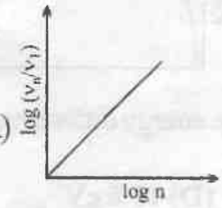
Q.39 Electron in a hydrogen atom is replaced by an identically charged particle muon with mass 207 times that of electron. Now the radius of K shell will be
(A) 2.56×10^{-3} Å (B) 109.7 Å (C) 1.21×10^{-3} Å (D) 22174.4 Å

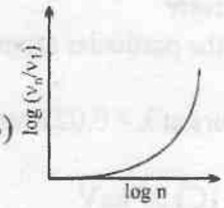
Q.40 Monochromatic radiation of wavelength λ is incident on a hydrogen sample containing in ground state. Hydrogen atoms absorb the light and subsequently emit radiations of ten different wavelengths. The value of λ is
(A) 95 nm (B) 103 nm (C) 73 nm (D) 88 nm

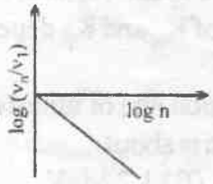
Q.41 When a hydrogen atom, initially at rest emits, a photon resulting in transition $n = 5 \rightarrow n = 1$, its recoil speed is about
(A) 10^{-4} m/s (B) 2×10^{-2} m/s (C) 4.2 m/s (D) 3.8×10^{-2} m/s

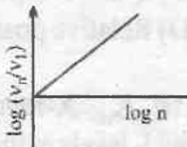
Q.42 An electron collides with a fixed hydrogen atom in its ground state. Hydrogen atom gets excited and the colliding electron loses all its kinetic energy. Consequently the hydrogen atom may emit a photon corresponding to the largest wavelength of the Balmer series. The min. K.E. of colliding electron will be
(A) 10.2 eV (B) 1.9 eV (C) 12.1 eV (D) 13.6 eV

Q.43 The frequency of revolution of electron in n^{th} Bohr orbit is ν_n. The graph between log n and log (ν_n / ν_1) may be

(A) 

(B) 

(C) 

(D) 

Q.44 Consider the spectral line resulting from the transition $n = 2 \rightarrow n = 1$ in the atoms and ions given below. The shortest wavelength is produced by :
(A) hydrogen atom (B) deuterium atom
(C) singly ionized helium (D) doubly ionized lithium

Q.45 In an atom, two electrons move around the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is : (neglect electric interaction)
(A) 1 : 4 (B) 4 : 1 (C) 1 : 8 (D) 8 : 1

Q.46 The electron in hydrogen atom in a sample is in n^{th} excited state, then the number of different spectrum lines obtained in its emission spectrum will be :
(A) $1 + 2 + 3 + ...+(n - 1)$ (B) $1 + 2 + 3 + ...+ (n)$
(C) $1 + 2 + 3 + ...+(n + 1)$ (D) $1 \times 2 \times 3 \times ....\times (n - 1)$

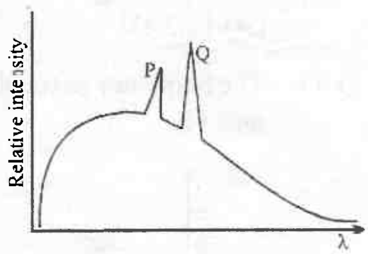
Q.47 The total energy of a hydrogen atom in its ground state is -13.6eV. If the potential energy in the first excited state is taken as zero then the total energy in the ground state will be :
(A) -3.4eV (B) 3.4 eV (C) – 6.8eV (D) 6.8eV

Q.48 A neutron collides head on with a stationary hydrogen atom in ground state
(A) If kinetic energy of the neutron is less than 13.6eV, collision must be elastic
(B) if kinetic energy of the neutron is less than 13.6eV, collision may be inelastic.
(C) inelastic collision takes place when initial kinetic energy of neutron is greater than 13.6eV.
(D) perfectly inelastic collision cannot take place.

Q.49 The electron in a hydrogen atom make a transition from an excited state to the ground state. Which of the following statement is true ?
(A) Its kinetic energy increases and its potential and total energies decrease
(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same.
(C) Its kinetic and toal energies decrease and its potential energy increases.
(D) its kinetic potential and total energies decreases.

Q.50 The magnitude of angular momentum, orbit radius and frequency of revolution of electron in hydrogen atom corresponding to quantum number n are L, r and f respectively Then according to Bohr's theory of hydrogen atom,
(A) fr^2L is constant for all orbits
(B) frL is constant for all orbits
(C) f^2rL is constant for all orbits
(D) frL^2 is constant for all orbits

Q.51 In a characteristic X– ray spectra of some atom superimposed on continuous X– ray spectra:
(A) P represents K_α line
(B) Q represents K_β line
(C) Q and P represents K_α and K_β lines respectively
(D) Relative positions of K_α and K_β depend on the particular atom



Q.52 The "K_α" X-rays emission line of tungsten occurs at $\lambda = 0.021$ nm. The energy difference between K and L levels in this atom is about
(A) 0.51 MeV
(B) 1.2 MeV
(C) 59 keV
(D) 13.6 eV

Q.53 Consider the nuclear reaction

$$X^{200} \longrightarrow A^{110} + B^{90}$$

If the binding energy per nucleon for X, A and B is 7.4 MeV, 8.2. MeV and 8.2 MeV respectively, what is the energy released ?
(A) 200 MeV
(B) 160 MeV
(C) 110 MeV
(D) 90 MeV

Q.54 The binding energy per nucleon for C^{12} is 7.68 MeV and that for C^{13} is 7.5 MeV The energy required to remove a neutron from C^{13} is
(A) 5.34 MeV
(B) 5.5 MeV
(C) 9.5 MeV
(D) 9.34 MeV

Q.55 The binding energies of nuclei X and Y are E_1 and E_2 respectively. Two atoms of X fuse to give one atom of Y and an energy Q is released. Then:
(A) $Q = 2E_1 - E_2$
(B) $Q = E_2 - 2E_1$
(C) $Q = 2E_1 + E_2$
(D) $Q = 2E_2 + E_1$

Q.56 Radius of the second Bohr obit of singly ionised helium atom is
(A) 0.53 Å
(B) 1.06 Å
(C) 0.265 Å
(D) 0.132 Å

Q.57 An electron in Bohr's hydrogen atom has an energy of –3.4 eV. The angular momentum of the electron is
(A) h/π
(B) $h/2\pi$
(C) $nh/2\pi$ (n is an integer)
(D) $2h/\pi$

Q.58 If each fission in a U^{235} nucleus releases 200 MeV, how many fissions must occurs per second to produce a power of 1 KW
(A) 1.325×10^{13} (B) 3.125×10^{13} (C) 1.235×10^{13} (D) 2.135×10^{13}

Q.59 The rest mass of the deuteron, ${}_1^2H$, is equivalent to an energy of 1876 MeV, the rest mass of a proton is equivalent to 939 MeV and that of a neutron to 940 MeV. A deuteron may disintegrate to a proton and a neutron if it :
(A) emits a γ-ray photon of energy 2 MeV
(B) captures a γ-ray photon of energy 2 MeV
(C) emits a γ-ray photon of energy 3 MeV
(D) captures a γ-ray photon of energy 3 MeV

Q.60 In an α-decay the Kinetic energy of α particle is 48 MeV and Q-value of the reaction is 50 MeV. The mass number of the mother nucleus is: (Assume that daughter nucleus is in ground state)
(A) 96 (B) 100 (C) 104 (D) none of these

Q.61 In the uranium radioactive series the initial nucleus is ${}_{92}U^{238}$, and the final nucleus is ${}_{82}Pb^{206}$. When the uranium nucleus decays to lead, the number of α – particles emitted is.. and the number of β-particles emitted...
(A) 6, 8 (B) 8, 6 (C) 16, 6 (D) 32, 12

Q.62 The radioactive sources A and B of half lives of 2 hr and 4 hr respectively, initially contain the same number of radioactive atoms. At the end of 2 hours, their rates of disintegration are in the ratio :
(A) 4 : 1 (B) 2 : 1 (C) $\sqrt{2}$: 1 (D) 1 : 1

Q.63 In a RA element the fraction of initiated amount remaining after its mean life time is
(A) $1-\frac{1}{e}$ (B) $\frac{1}{e^2}$ (C) $\frac{1}{e}$ (D) $1-\frac{1}{e^2}$

Q.64 90% of a radioactive sample is left undecayed after time t has elapsed. What percentage of the initialsample will decay in a total time 2t:
(A) 20% (B) 19% (C) 40% (D) 38%

Q.65 A radioactive material of half-life T was produced in a nuclear reactor at different instants, the quantity produced second time was twice of that produced first time. If now their present activities are A_1 and A_2 respectively then their age difference equals:
(A) $\frac{T}{\ln 2}\left|\ln\frac{A_1}{A_2}\right|$ (B) $T\left|\ln\frac{A_1}{A_2}\right|$ (C) $\frac{T}{\ln 2}\left|\ln\frac{A_2}{2A_1}\right|$ (D) $T\left|\ln\frac{A_2}{2A_1}\right|$

Q.66 Activity of a radioactive substance is R_1 at time t_1 and R_2 at time $t_2 (t_2 > t_1)$. Then the ratio $\frac{R_2}{R_1}$ is:
(A) $\frac{t_2}{t_1}$ (B) $e^{-\lambda(t_1+t_2)}$ (C) $e\left(\frac{t_1-t_2}{\lambda}\right)$ (D) $e^{\lambda(t_1-t_2)}$

Q.67 There are two radionuclei A and B. A is an alpha emitter and B is a beta emitter. Their distintegration constants are in the ratio of 1 : 2. What should be the ratio of number of atoms of two at time t = 0 so that probabilities of getting α and β particles are same at time t = 0.
(A) 2 : 1 (B) 1 : 2 (C) e (D) e^{-1}

Q.68 The activity of a sample reduces from A_0 to $A_0/\sqrt{3}$ in one hour. The activity after 3 hours more will be

(A) $\frac{A_0}{3\sqrt{3}}$ (B) $\frac{A_0}{9}$ (C) $\frac{A_0}{9\sqrt{3}}$ (D) $\frac{A_0}{27}$

Q.69 Half life of radium is 1620 years. How many radium nuclei decay in 5 hours in 5 gm radium? (Atomic weight of radium = 223)

(A) 9.1×10^{12} (B) 3.23×10^{15} (C) 1.72×10^{20} (D) 3.3×10^{17}

Q.70 Half life for certain radioactive element is 5 min. Four nuclei of that element are observed at a certain instant of time. After five minutes

Assertion (A): It can be definitely said that two nuclei will be left undecayed.

Reasoning (R): After half life i.e. 5 minutes, half of total nuclei will disintegrate. So only two nuclei will be left undecayed. Then

(A) **A** is correct & **R** is correct explanation of **A**.
(B) Both are correct. But **R** is not correct explanation of **A**.
(C) **A** is incorrect & **R** is correct.
(D) Both are incorrect.

Q.71 A certain radioactive nuclide of mass number m_x disintegrates, with the emission of an electron and γ radiation only, to give second nuclied of mass number m_y. Which one of the following equation correctly relates m_x and m_y?

(A) $m_y = m_x + 1$ (B) $m_y = m_x - 2$ (C) $m_y = m_x - 1$ (D) $m_y = m_x$

Q.72 The number of α and β^- emitted during the radioactive decay chain starting from ${}^{226}_{88}Ra$ and ending at ${}^{206}_{82}Pb$ is

(A) 3α & $6\beta^-$ (B) 4α & $5\beta^-$ (C) 5α & $4\beta^-$ (D) 6α & $6\beta^-$

Q.73 The activity of a sample of radioactive material is A_1 at time t_1 and A_2 at time t_2 ($t_2 > t_1$). Its mean life is T.

(A) $A_1t_1 = A_2t_2$ (B) $\frac{A_1 - A_2}{t_2 - t_1}$ = constant (C) $A_2 = A_1 e^{(t_1-t_2)/T}$ (D) $A_2 = A_1 e^{(t_1/Tt_2)}$

Q.74 A fraction f_1 of a radioactive sample decays in one mean life, and a fraction f_2 decays in one half–life.

(A) $f_1 > f_2$
(B) $f_1 < f_2$
(C) $f_1 = f_2$
(D) May be (A), (B) or (C) depending on the values of the mean life and half life

Q.75 A radioactive substance is being produced at a constant rate of 10 nuclei/s. The decay constant of the substance is 1/2 sec^{-1}. After what time the number of radioactive nuclei will become 10? Initially there are no nuclei present. Assume decay law holds for the sample.

(A) 2.45 sec (B) log (2) sec (C) 1.386 sec (D) $\frac{1}{ln(2)}$ sec

Q.76 The radioactivity of a sample is R_1 at time T_1 and R_2 at time T_2. If the half life of the specimen is T. Number of atoms that have disintegrated in time $(T_2 - T_1)$ is proportional to

(A) $(R_1T_1 - R_2T_2)$ (B) $(R_1 - R_2)$ T (C) $(R_1 - R_2)/T$ (D) $(R_1 - R_2)(T_1 - T_2)$

Q.77 The decay constant of the end product of a radioactive series is
(A) zero (B) infinite (C) finite (non zero) (D) depends on the end product.

Q.78 At time t = 0, N_1 nuclei of decay constant λ_1 & N_2 nuclei of decay constant λ_2 are mixed. The decay rate of the mixture is :

(A) $N_1N_2e^{-(\lambda_1+\lambda_2)t}$

(B) $+\left(\frac{N_1}{N_2}\right)e^{-(\lambda_1-\lambda_2)t}$

(C) $+\left(N_1\lambda_1e^{-\lambda_1 t}+N_2\lambda_2e^{-\lambda_2 t}\right)$

(D) $+N_1\lambda_1N_2\lambda_2e^{-(\lambda_1+\lambda_2)t}$

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 In photoelectric effect, stopping potential depends on
(A) frequency of the incident light
(B) intensity of the incident light by varies source distance
(C) emitter's properties
(D) frequency and intensity of the incident light

Q.2 An electron in hydrogen atom first jumps from second excited state to first excited state and then, from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons in the two cases be x, y and z, then select the wrong answer/(s) :
(A) $z = 1/x$
(B) $x=9/4$
(C) $y=5/27$
(D) $z=5/27$

Q.3 An electron is in an excited state in hydrogen-like atom. It has a total energy of -3.4 eV. If the kinetic energy of the electron is E and its de-Broglie wavelength is λ, then
(A) $E = 6.8$ eV, $\lambda = 6.6 \times 10^{-10}$ m
(B) $E = 3.4$ eV, $\lambda = 6.6 \times 10^{-10}$ m
(C) $E = 3.4$ eV, $\lambda = 6.6 \times 10^{-11}$ m
(D) $E = 6.8$ eV, $\lambda = 6.6 \times 10^{-11}$ m

Q.4 A particular hydrogen like atom has its ground state binding "energy 122.4eV. Its is in ground state. Then:
(A) Its atomic number is 3
(B) An electron of 90eV can excite it.
(C) An electron of kinetic energy nearly 91.8eV can be brought to almost rest by this atom.
(D) An electron of kinetic energy 2.6eV may emerge from the atom when electron of kinetic energy 125eV collides with this atom.

Q.5 A beam of ultraviolet light of all wavelengths passes through hydrogen gas at room temperature, in the x-direction. Assume that all photons emitted due to electron transition inside the gas emerge in the y-direction. Let A and B denote the lights emerging from the gas in the x and y directions respectively.
(A) Some of the incident wavelengths will be absent in A.
(B) Only those wavelengths will be present in B which are absent in A.
(C) B will contain some visible light.
(D) B will contain some infrared light.

Q.6 If radiation of allow wavelengths from ultraviolet to infrared is passed through hydrogen agas at room temperature, absorption lines will be observed in the :
(A) Lyman series
(B) Balmer series
(C) both (A) and (B)
(D) neither (A) nor (B)

Q.7 In the hydrogen atom, if the reference level of potential energy is assumed to be zero at the ground state level. Choose the incorrect statement.
(A) The total energy of the shell increases with increase in the value of n
(B) The total energy of the shell decrease with increase in the value of n.
(C) The difference in total energy of any two shells remains the same.
(D) The total energy at the ground state becomes 13.6 eV.

Q.8 Choose the correct statement(s) for hydrogen and deuterium atoms (considering motion of nucleus)
(A) The radius of first Bohr orbit of deuterium is less than that of hydrogen
(B) The speed of electron in the first Bohr orbit of deuterium is more than that of hydrogen.
(C) The wavelength of first Balmer line of deuterium is more than that of hydrogen
(D) The angular momentum of electron in the first Bohr orbit of deuterium is more than that of hydrogen.

Q.9 Let A_n be the area enclosed by the nth orbit in a hydrogen atom. The graph of $\ln (A_n/A_1)$ agains $\ln (n)$.
(A) will pass through origin
(B) will be a stright line will slope 4
(C) will be a monotonically increasing nonlinear curve
(D) will be a circle.

Q.10 A neutron collides head-on with a stationary hydrogen atom in ground state. Which of the following statements are correct (Assume that the hydrogen atom and neutron has same mass):
(A) If kinetic energy of the neutron is less than 20.4 eV collision must be elastic.
(B) If kinetic energy of the neutron is less than 20.4 eV collision may be inelastic.
(C) Inelastic collision may be take place only when initial kinetic energy of neutron is greater than 20.4 eV.
(D) Perfectly inelastic collision can not take place.

Q.11 When a nucleus with atomic number Z and mass number A undergoes a radioactive decay process:
(A) both Z and A will decrease, if the process is α decay
(B) Z will decrease but A will not change, if the process is β^+ decay
(C) Z will decrease but A will not change, if the process is β^- decay
(D) Z and A will remain unchanged, if the process is γ decay.

Q.12 In a Coolidge tube experiment, the minimum wavelength of the continuous X-ray spectrum is equal to 66.3 pm, then
(A) electrons accelerate through a potential difference of 12.75 kV in the Coolidge tube
(B) electrons accelerate through a potential difference of 18.75 kV in the Coolidge tube
(C) de-Broglie wavelength of the electrons reaching the anticathode is of the order of 10μm.
(D) de-Broglie wavelength of the electrons reaching the anticathode is 0.01Å.

Q.13 The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation:
(A) the intensity increases
(B) the minimum wave length increases
(C) the intensity decreases
(D) the minimum wave length decreases

Q.14 When the atomic number A of the nucleus increases
(A) initially the neutron–proton ratio is constant = 1
(B) initially neutron–proton ratio increases and later decreases
(C) initially binding energy per nucleon increases and later decreases
(D) the binding energy per nucleon increases when the neutron–proton ratio increases.

Q.15 Let m_p be the mass of a proton, m_n the mass of a neutron, M_1 the mas of a ${}^{20}_{10}Ne$ nucleus and M_2 the mass of a ${}^{40}_{20}Ca$ nucleus. Then
(A) $M_2 = 2M_1$
(B) $M_2 > 2M_1$
(C) $M_2 < 2M_1$
(D) $M_1 < 10(m_n + m_p)$

Q.16 The decay constant of a radio active substance is 0.173 $(\text{years})^{-1}$. Therefore :
(A) Nearly 63% of the radioactive substance will decay in (1/0.173) year.
(B) half life of the radio active substance is (1/0.173) year.
(C) one -forth of the radioactive substance will be left after nearly 8 years.
(D) all the above statements are true.

ANSWER KEY

ONLY ONE OPTION IS CORRECT

Q.1	C	Q.2	B	Q.3	C	Q.4	D	Q.5	D	Q.6	C	Q.7	A
Q.8	D	Q.9	A	Q.10	A	Q.11	B	Q.12	~~C~~ B	Q.13	D	Q.14	C
Q.15	D	Q.16	C	Q.17	C	Q.18	A	Q.19	C	Q.20	B	Q.21	B
Q.22	B	Q.23	A	Q.24	B	Q.25	A	Q.26	A	Q.27	B	Q.28	C
Q.29	A	Q.30	C	Q.31	D	Q.32	A	Q.33	D	Q.34	C	Q.35	D
Q.36	B	Q.37	C	Q.38	A	Q.39	A	Q.40	A	Q.41	C	Q.42	C
Q.43	C	Q.44	D	Q.45	C	Q.46	B	Q.47	C	Q.48	A	Q.49	A
Q.50	B	Q.51	C	Q.52	C	Q.53	B	Q.54	A	Q.55	B	Q.56	B
Q.57	A	Q.58	B	Q.59	D	Q.60	B	Q.61	B	Q.62	C	Q.63	C
Q.64	B	Q.65	C	Q.66	D	Q.67	A	Q.68	B	Q.69	B	Q.70	D
Q.71	D	Q.72	C	Q.73	C	Q.74	A	Q.75	C	Q.76	B	Q.77	A
Q.78	C												

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Q.1	A,C	Q.2	B	Q.3	B	Q.4	A,C,D
Q.5	A,C,D	Q.6	A	Q.7	B	Q.8	A
Q.9	A,B	Q.10	A,C	Q.11	A,B,D	Q.12	B
Q.13	A,D	Q.14	A,C	Q.15	C,D	Q.16	A,C

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

MODERN PHYSICS

CONTENTS

KEY CONCEPTS

1. **CATHODE RAYS :**

(a) Generated in a discharge tube in which a high vaccum is maintained .

(b) They are electrons accelerated by high p.d. (10 to 15 K.V.)

(c) K.E. of C.R. particle accelerated by a p.d. V is $\frac{1}{2}mv^2 = \frac{P^2}{2m} = eV$.

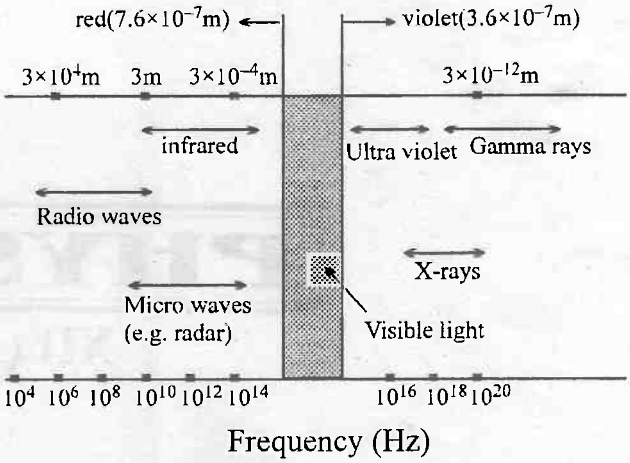
(d) Can be deflected by Electric & magnetic fields .

2. **ELECTROMAGNETIC SPECTRUM :**

Ordered arrangement of the big family of electro magnetic waves (EMW) either in ascending order of frequencies or of wave lengths

Speed of E.M.W. in vacuum

$C = 3 \times 10^8$ m/s $= \nu\lambda$



3. **PLANK'S QUANTUM THEORY :**

A beam of EMW is a stream of discrete packets of energy called **PHOTONS** , each photon having a frequency ν and energy $= E = h\nu$.

h = plank 's constant $= 6.63 \times 10^{-34}$ Js .

4. **PHOTO ELECTRIC EFFECT :**

The phenomenon of the emission of electrons , when metals are exposed to light (of a certain minimum frequency) is called photo electric effect.

Results :

(i) Can be explained only on the basis of the quantum theory (concept of photon) .

(ii) Electrons are emitted if the incident light has frequency $\nu > \nu_0$ (threshold frequency) emission of electrons is independent of intensity . The wave length corresponding to ν_0 is called threshold wave length λ_0 .

(iii) ν_0 is different for different metals .

(iv) Number of electrons emitted per second depends on the intensity of the incident light .

(v) **EINSTEINS PHOTO ELECTRIC EQUATION :**

Photon energy = K. E. of electron + work function .

$$h\nu = \frac{1}{2}mv^2 + \phi$$

ϕ = **Work function = energy needed by the electron in freeing itself from the atoms of the metal .**

$$\phi = h\nu_0$$

(vi) **STOPPING POTENTIAL OR CUT OFF POTENTIAL :**

The minimum value of the retarding potential to prevent electron emission is :

$$eV_{cut\ off} = (KE)_{max}$$

Note : The number of photons incident on a surface per unit time is called photon flux.

5. **WAVE NATURE OF MATTER :**

Beams of electrons and other forms of matter exhibit wave properties including interference and diffraction with a de Broglie wave length given by $\lambda = \frac{h}{p}$

(wave length of a praticle) .

6. **ATOMIC MODELS :**

(a) **THOMSON MODEL : (PLUM PUDDING MODEL)**

(i) Most of the mass and all the positive charge of an atom is uniformly distributed over the full size of atom (10^{-10} m).

(ii) Electrons are studded in this uniform distribution.

(iii) Failed to explain the large angle scattering α - particle scattered by thin foils of matter.

(b) **RUTHERFORD MODEL :** (Nuclear Model)

(i) The most of the mass and all the positive charge is concentrated within a size of 10^{-14} m inside the atom. This concentration is called the atomic nucleus.

(ii) The electron revolves around the nucleus under electric interaction between them in circular orbits. An accelerating charge radiates the nucleus spiralling inward and finally fall into the nucleus, which does not happen in an atom. This could not be explained by this model.

(c) **BOHR ATOMIC MODEL :**

Bohr adopted Rutherford model of the atom & added some arbitrary conditions. These conditions are known as his postulates :

(i) The electron in a stable orbit does not radiate energy. i.e. $\frac{mv^2}{r} = \frac{kze^2}{r^2}$

(ii) A stable orbit is that in which the angular momentum of the electron about nucleus is an integral (n) multiple of $\frac{h}{2\pi}$. i.e. $mvr = n\frac{h}{2\pi}$; $n = 1, 2, 3, \ldots\ldots (n \neq 0)$.

(iii) The electron can absorb or radiate energy only if the electron jumps from a lower to a higher orbit or falls from a higher to a lower orbit.

(iv) The energy emitted or absorbed is a light photon of frequency ν and of energy. $\mathbf{E = h\nu}$.

FOR HYDROGEN ATOM : (Z = atomic number = 1)

(i) L_n = angular momentum in the nth orbit $= n\frac{h}{2\pi}$.

(ii) r_n = radius of nth circular orbit $= (0.529\ A^o)\ n^2$; $(1A^o = 10^{-10}\ m)$; $r_n \propto n^2$.

(iii) E_n Energy of the electron in the nth orbit $= \frac{-13.6\ ev}{n^2}$ i.e. $E_n \propto \frac{1}{n^2}$.

Note : Total energy of the electron in an atom is negative, indicating that it is bound.

Binding Energy $(BE)_n = -E_n = \frac{13.6\ ev}{n^2}$

(iv) $E_{n2} - E_{n1}$ = Energy emitted when an electron jumps from n_2^{th} orbit to n_1^{th} orbit $(n_2 > n_1)$.

$\Delta E = (13.6\ ev)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

$\Delta E = h\nu$; ν = frequency of spectral line emitted.

$\frac{1}{\lambda} = \bar{\nu}$ = wave no. [no. of waves in unit length (1m)] $= R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

Where R = Rydberg's constant for hydrogen $= 1.097 \times 10^7\ m^{-1}$.

(v) For hydrogen like atom/spicies of atomic number Z :

$r_{nz} = \frac{\text{Bohr radius}}{Z}\ n^2 = (0.529\ A^o)\frac{n^2}{Z}$; $E_{nz} = (-13.6)\frac{Z^2}{n^2}$ ev

$R_z = RZ^2$ – Rydberg's constant for element of atomic no. Z.

Note : If motion of the nucleus is also considered, then m is replaced by μ.

Where μ = reduced mass of electron - nucleus system = mM/(m+M).

In this case $E_n = (-13.6 \text{ ev}) \frac{Z^2}{n^2} \cdot \frac{\mu}{m_e}$

7. **SPECTRAL SERIES :**

(i) **Lyman Series :** (Landing orbit n = 1).

Ultraviolet region $\bar{v} = R\left[\frac{1}{1^2} - \frac{1}{n_2^{\,2}}\right]$; $n_2 > 1$

(ii) **Balmer Series :** (Landing orbit n = 2)

Visible region $v = R\left[\frac{1}{2^2} - \frac{1}{n_2^{\,2}}\right]$; $n_2 > 2$

(iii) **Paschan Series :** (Landing orbit n = 3)

In the near infrared region $\bar{v} = R\left[\frac{1}{3^2} - \frac{1}{n_2^{\,2}}\right]$; $n_2 > 3$

(iv) **Bracket Series :** (Landing orbit n = 4)

In the mid infrared region $\bar{v} = R\left[\frac{1}{4^2} - \frac{1}{n_2^{\,2}}\right]$; $n_2 > 4$

(v) **Pfund Series :** (Landing orbit n = 5)

In far infrared region $\bar{v} = R\left[\frac{1}{5^2} - \frac{1}{n_2^{\,2}}\right]$; $n_2 > 5$

In all these series n_2 = $n_1 + 1$ is the α line
= $n_1 + 2$ is the β line
= $n_1 + 3$ is the γ line .... etc. where n_1 = Landing orbit

8. **EXCITATION POTENTIAL OF ATOM :**

Excitation potential for quantum jump from $n_1 \longrightarrow n_2 = \frac{E_{n2} - E_{n1}}{\text{electron charge}}$.

9. **IONIZATION ENERGY :**

The energy required to remove an electron from an atom. The energy required to ionize hydrogen atom is = 0 - (- 13.6) = 13.6 ev.

10. **IONIZATION POTENTIAL :**

Potential difference through which an electron is moved to gain ionization energy = $\frac{-E_n}{\text{electronic charge}}$

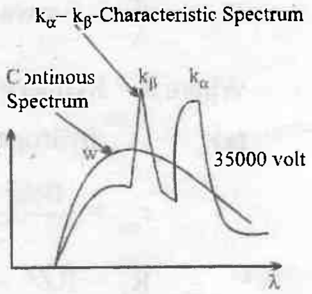
11. **X - RAYS :**

(i) Short wavelength (0.1 A° to 1 A°) electromagnetic radiation.

(ii) Are produced when a metal anode is bombarded by very high energy electrons.

(iii) Are not affected by electric and magnetic field.

(iv) They cause photoelectric emission.



Characteristics equation $eV = h\nu_m$

e = electron charge ;

V = accelerating potential

ν_m = maximum frequency of X - radiation

(v) Intensity of X - rays depends on number of electrons hitting the target .

(vi) Cut off wavelength or minimum wavelength, where v (in volts) is the p.d. applied to the tube

$\lambda_{min} = \frac{12400}{V}$ A°.

(vii) Continuous spectrum due to retardation of electrons .

(viii) Characteristic Spectrum due to transition of electron from higher to lower

$v \propto (z - b)^2$; $\upsilon = a(z - b)^2$ [MOSELEY'S LAW]

b = 1 for K series ; b = 7.4 for L series

Where b is Shielding factor (different for different series) .

Note : (i) Binding energy = - [Total Mechanical Energy]

(ii) Vel. of electron in nth orbit for hydrogen atom $\cong \frac{c}{137n}$; c = speed of light .

(iii) For x - rays $\frac{1}{\lambda} = R(z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

(iv) Series limit of series means minimum wave length of that series.

12. NUCLEAR DIMENSIONS :

$R = R_o A^{1/3}$. Where R_o = empirical constant = 1.1×10^{-15} m ; A = Mass number of the atom

13. RADIOACTIVITY :

The phenomenon of self emission of radiation is called radioactivity and the substances which emit these radiations are called **radioactive substances** . It can be natural or artificial (induced) .

14. α , β , γ RADIATION :

(i) α − particle :

(a) Helium nucleus ($_2He^4$) ; **(b)** energy varies from 4 Mev to 9 Mev ;

(c) Velocity 10^6 − 10^7 m/s ; **(d)** low penetration

(ii) β − particle :

(a) Have much less energy ; **(b)** more penetration ; **(c)** higher velocities than α particles

(iii) γ − radiation : Electromagnetic waves of very high energy .

15. LAWS OF RADIOACTIVE DISINTEGRATION :

(A) DISPLACEMENT LAW : In all radioactive transformation either an α or β particle (never both or more than one of each simultaneously) is emitted by the nucleus of the atom.

(i) α − emission : $_zX^A \longrightarrow {}_{z-2}Y^{A-4} + {}_2\alpha^4$ + Energy

(ii) β − emission : $_zX^A \longrightarrow \beta + {}_{z+1}Y^A + \bar{v}$ (antinuetrino)

(iii) γ − emission : emission does not affect either the charge number or the mass number .

(B) STASTISTICAL LAW : The disintegration is a random phenomenon . Whcih atom disintegrates first is purely a matter of chance .

Number of nuclei disintegrating per second is given ;

(disintegration /s /gm is called specific activity) .

(i) $\frac{dN}{dt} \alpha N \rightarrow \frac{dN}{dt} = -\lambda N$ = activity .

Where N = No. of nuclei present at time t ; λ − decay constant

(ii) $N = N_o e^{-\lambda t}$ N_o = number of nuclei present in the beginning .

(iii) Half life of the population $T_{1/2} = \frac{0.693}{\lambda}$;

at the end of n half–life periods the number of nuclei left $N = \frac{N_0}{2^n}$.

(iv) MEAN LIFE OF AN ATOM $= \frac{\Sigma \text{lifetime of all atoms}}{\text{total number of atoms}}$; $T_{av} = \frac{1}{\lambda}$

(v) **CURIE :** The unit of activity of any radioactive substance in which the number of disintegration per second is 3.7×10^{10} .

16. ATOMIC MASS UNIT (a.m.u. OR U) :

1 amu $= \frac{1}{12} \times$ (mass of carbon – 12 atom) $= 1.6603 \times 10^{-27}$ kg

17. MASS AND ENERGY :

The mass m of a particle is equivalent to an energy given by $E = mc^2$;
c = speed of light . 1 amu = 931 Mev

18. MASS DEFECT AND BINDING ENERGY OF A NUCLEUS :

The nucleus is less massive than its constituents . The difference of masses is called mass defect .
ΔM = mass defect $= [Z_{mp} + (A - Z) m_n] - M_{zA}$.

Total energy required to be given to the nucleus to tear apart the individual nucleons composing the nucleus, away from each other and beyond the range of interaction forces is called the Binding Energy of a nucleus .

B.E. $= (\Delta M)C^2$.

B.E. per nucleon $= \frac{(\Delta M)C^2}{A}$

Greater the B.E. , greater is the stability of the nucleus .

19. NUCLEAR FISSION :

(i) Heavy nuclei of A, above 200, break up onto two or more fragments of comparable masses.

(ii) The total B.E. increases and excess energy is released

(iii) The man point of the fission energy is leberated in the form of the K.E. of the fission fragments

eg. ${}^{235}_{92}U + {}_0n^1 \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}_0n^1$ + energy

20. NUCLEAR FUSION (Thermo nuclear reaction) :

(i) Light nuclei of A below 20, fuse together, the B.E. per nucleon increases and hence the excess energy is released .

(ii) These reactions take place at ultra high temperature ($\simeq 10^7$ to 10^9)

(iii) Energy released exceeds the energy liberated in the fission of heavy nuclei .

eg . $4\,{}^1_1P \rightarrow {}^4_1He + {}^0_{+1}e$. (Positron)

(iv) The energy released in fusion is specified by specifying Q value
i.e. Q value of reaction = energy released in a reaction .

Note : **(i)** In emission of β^-, z increases by 1 .

(ii) In emission of β^+, z decreases by 1 .

EXERCISE # I

Q.1 A parallel beam of uniform, monochromatic light of wavelength 2640 A has an intensity of $200 W/m^2$. The number of photons in $1 mm^3$ of this radiation are ....

Q.2 When photons of energy 4.25eV strike the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_a eV and de Broglie wavelength λ_a. The maximum kinetic energy of photoelectrons liberated from another metal B by photons of energy 4.7eV is $T_b = (T_a - 1.5)$ eV. If the De Broglie wavelength of these photoelectrons is $\lambda_b = 2\lambda_a$, then find

(a) The work function of a (b) The work function of b is (c) T_a and T_b

Q.3 When a monochromatic point source of light is at a distance of 0.2 m from a photoelectric cell, the cut off voltage and the saturation current are respectively 0.6 volt and 18.0 mA. If the same source is placed 0.6 m away from the photoelectric cell, then find

(a) the stopping potential (b) the saturation current

Q.4 An isolated metal body is illuminated with monochromatic light and is observed to become charged to a steady positive potential 1.0 V with respect to the surrounding. The work function of the metal is 3.0 eV. The frequency of the incident light is ______________.

Q.5 663 mW of light from a 540 nm source is incident on the surface of a metal. If only 1 of each 5×10^9 incident photons is absorbed and causes an electron to be ejected from the surface, the total photocurrent in the circuit is ________.

Q.6 Light of wavelength 330 nm falling on a piece of metal ejects electrons with sufficient energy which requires voltage V_0 to prevent a collector. In the same setup, light of wavelength 220 nm, ejects electrons which require twice the voltage V_0 to stop them in reaching a collector. Find the numerical value of voltage V_0.(Take plank's constant, $h = 6.6 \times 10^{-34}$ Js and $1 eV = 1.6 \times 10^{-19}$ J)

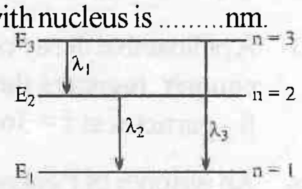
Q.7 A hydrogen atom in a state having a binding energy 0.85eV makes a transition to a state of excitation energy 10.2eV. The wave length of emitted photon is ....nm.

Q.8 A hydrogen atom is in 5th excited state. When the electron jumps to ground state the velocity of recoiling hydrogen atom is .... m/s and the energy of the photon is ....eV.

Q.9 The ratio of series limit wavlength of Balmer series to wavelength of first line of paschen series is ....

Q.10 An electron joins a helium nucleus to form a He+ ion. The wavelength of the photon emitted in this process if the electron is assumed to have had no kinetic energy when it combines with nucleus is ....nm.

Q.11 Three energy levels of an atom are shown in the figure. The wavelength corresponding to three possible transition are λ_1, λ_2 and λ_3. The value of λ_3 in terms of λ_1 and λ_2 is given by ______.



Q.12 Imagine an atom made up of a proton and a hypothetical particle of double the mass of an electron but having the same charge as the electron. Apply the Bohr atom model and consider a possible transitions of this hypothetical particle to the first excited level. Find the longest wavelngth photon that will be emitted λ (in terms of the Rydberg constant R.)

Q.13 In a hydrogen atom, the electron moves in an orbit of radius 0.5 Å making 10^{16} revolution per second. The magnetic moment associated with the orbital motion of the electron is ________.

Q.14 The positron is a fundamental particle with the same mass as that of the electron and with a charge equal to that of an electron but of opposite sign. When a positron and an electron collide, they may annihilate each other. The energy corresponding to their mass appears in two photons of equal energy. Find the wavelength of the radiation emitted.

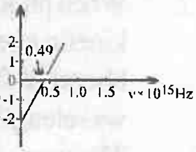
[Take : mass of electron = $(0.5/C^2)$MeV and $hC = 1.2 \times 10^{-12}$ MeV.m where h is the Plank's constant and C is the velocity of light in air]

Q.15 A small 10W source of ultraviolet light of wavelength 99 nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximately 0.05 nm. Find

(i) the average number of photons striking an atom per second.

(ii) the number of photoelectrons emitted per unit area per second if the efficiency of liberation of photoelectrons is 1%.

Q.16 The surface of cesium is illuminated with monochromatic light of various wavelengths and the stopping potentials for the wavelengths are measured. The results of this experiment is plotted as shown in the figure. Estimate the value of work function of the cesium and Planck's constant.



Q.17 A hydrogen like atom has its single electron orbiting around its stationary nucleus. The energy to excite the electron from the second Bohr orbit to the third Bohr orbit is 47.2 eV. The atomic number of this nucleus is ______________.

Q.18 A single electron orbits a stationary nucleus of charge Ze where Z is a constant and e is the electronic charge. It requires 47.2eV to excite the electron from the 2nd Bohr orbit to 3rd Bohr orbit. Find

(i) the value of Z,

(ii) energy required to excite the electron from the third to the fourth orbit

(iii) the wavelength of radiation required to remove the electron from the first orbit to infinity

(iv) the kinetic energy, potential energy and angular momentum in the first Bohr orbit

(v) the radius of the first Bohr orbit.

Q.19 A hydrogen like atom (atomic number Z) is in higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energy 22.95eV and 5.15eV respectively. Alternatively, the atom from the same excited state can make transition to the second excited state by successively emitting two photons of energies 2.4eV and 8.7eV respectively. Find the values of n and Z.

Q.20 Find the binding energy of an electron in the ground state of a hydrogen like atom in whose spectrum the third of the corresponding Balmer series is equal to 108.5nm.

Q.21 Which level of the doubly ionized lithium has the same energy as the ground state energy of the hydrogen atom. Find the ratio of the two radii of corresponding orbits.

Q.22 The binding energies per nucleon for deuteron ($_1H^2$) and helium ($_2He^4$) are 1.1 MeV and 7.0 MeV respectively. The energy released when two deuterons fuse to form a helium nucleus ($_2He^4$) is ______.

Q.23 A radioactive decay counter is switched on at t = 0. A β - active sample is present near the counter. The counter registers the number of β - particles emitted by the sample. The counter registers 1×10^5 β - particles at t = 36 s and 1.11×10^5 β - particles at t = 108 s. Find $T_{1/2}$ of this sample

Q.24 An isotopes of Potassium $^{40}_{19}K$ has a half life of 1.4×10^9 year and decays to Argon $^{40}_{18}Ar$ which is stable.

(i) Write down the nuclear reaction representing this decay.

(ii) A sample of rock taken from the moon contains both potassium and argon in the ratio 1/7. Find age of rock

Q.25 At t = 0, a sample is placed in a reactor. An unstable nuclide is produced at a constant rate R in the sample by neutron absorption. This nuclide β^- decays with half life τ. Find the time required to produce 80% of the equilibrium quantity of this unstable nuclide.

Q.26 Suppose that the Sun consists entirely of hydrogen atom and releases the energy by the nuclear reaction, $4\,{}_1^1H \longrightarrow {}_2^4He$ with 26 MeV of energy released. If the total output power of the Sun is assumed to remain constant at 3.9×10^{26} W, find the time it will take to burn all the hydrogen. Take the mass of the Sun as 1.7×10^{30} kg.

Q.27 Assuming that the source of the energy of solar radiation is the energy of the formation of helium from hydrogen according to the following cyclic reaction :

$${}_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} \rightarrow {}_6C^{13} + {}_{+1}e^0$$

$${}_6C^{13} + {}_1H^1 \rightarrow {}_7N^{14}$$

$${}_7N^{14} + {}_1H^1 \rightarrow {}_8O^{15} \rightarrow {}_7N^{15} + {}_{+1}e^0$$

$${}_7N^{15} + {}_1H^1 \rightarrow {}_6C^{12} + {}_2He^4$$

Find how many tons of hydrogen must be converted every second into helium . The solar constant is $8\ J/cm^2$ min. Assume that hydrogen forms 35% of the sun's mass . Calculate in how many years this hydrogen will be used up if the radiation of the sun is constant . $m_e = 5.49 \times 10^{-4}$ amu, atomic masses m_H=1.00814 amu, m_{He}=4.00388 amu, mass of the sun=2×10^{30} kg, distance between the sun and the earth= 1.5×10^{11}m. 1 amu = 931 MeV.

Q.28 An electron of mass "m" and charge "e" initially at rest gets accelerated by a constant electric field E. The rate of change of DeBroglie wavelength of this electron at time t is ....

List of recommended questions from I.E. Irodov.

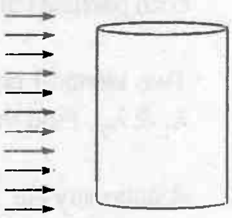
5.247, 5.249, 5.260, 5.262, 5.263, 5.264, 5.265, 5.266, 5.270, 5.273, 5.277
6.21, 6.22, 6.27, 6.28, 6.30, 6.31, 6.32, 6.33, 6.35, 6.37, 6.38, 6.39, 6.40,
6.41, 6.42, 6.43, 6.49, 6.50, 6.51, 6.52, 6.53, 6.133, 6.134, 6.135, 6.136,
6.137, 6.138, 6.141, 6.214, 6.233, 6.249, 6.264, 6.289

EXERCISE # II

Q.1 Find the force exerted by a light beam of intensity I, incident on a cylinder (height h and base radius R) placed on a smooth surface as shown in figure if:

(a) surface of cylinder is perfectly reflecting

(b) surface of cylinder is having reflection coefficient 0.8. (assume no transmission)



Q.2 A small plate of a metal (work function = 1.17 eV) is placed at a distance of 2m from a monochromatic light source of wave length 4.8×10^{-7} m and power 1.0 watt. The light falls normally on the plate. Find the number of photons striking the metal plate per square meter per sec. If a constant uniform magnetic field of strength 10^{-4} tesla is applied parallel to the metal surface. Find the radius of the largest circular path followed by the emitted photoelectrons.

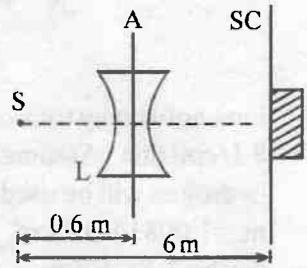
Q.3 Electrons in hydrogen like atoms (Z = 3) make transitions from the fifth to the fourth orbit & from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate & eject photo electrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volts. Calculate the work function of the metal, & the stopping potential for the photoelectrons ejected by the longer wavelength. (Rydberg constant = $1.094 \times 10^7\ m^{-1}$)

Q.4 A beam of light has three wavelengths 4144Å, 4972Å & 6216 Å with a total intensity of $3.6\times10^{-3}\ W.m^{-2}$ equally distributed amongst the three wavelengths. The beam falls normally on an area $1.0\ cm^2$ of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each energetically capable photon ejects one electron. Calculate the number of photoelectrons liberated in two seconds.

Q.5 Monochromatic radiation of wavelength $\lambda_1 = 3000 Å$ falls on a photocell operating in saturating mode. The corresponding spectral sensitivity of photocell is $J = 4.8 \times 10^{-3}$ A/w. When another monochromatic radiation of wavelength $\lambda_2 = 1650 Å$ and power $P = 5 \times 10^{-3}$ W is incident, it is found that maximum velocity of photoelectrons increases n = 2 times. Assuming efficiency of photoelectron generation per incident photon to be same for both the cases, calculate

(i) threshold wavelength for the cell. (ii) saturation current in second case.

Q.6 A monochromatic point source S radiating wavelength 6000 Å with power 2 watt, an aperture A of diameter 0.1 m & a large screen SC are placed as shown in figure. A photoemissive detector D of surface area 0.5 cm² is placed at the centre of the screen. The efficiency of the detector for the photoelectron generation per incident photon is 0.9.



(i) Calculate the photon flux density at the centre of the screen and the photocurrent in the detector.

(ii) If a concave lens L of focal length 0.6 m is inserted in the aperture as shown, find the new values of photon flux density & photocurrent Assume a uniform average transmission of 80% for the lens.

(iii) If the work-function of the photoemissive surface is 1 eV, calculate the values of the stopping potential in the two cases (without & with the lens in the aperture).

Q.7 A small 10 W source of ultraviolet light of wavelength 99 nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximaterly 0.05 nm. Find :

(i) the number of photons striking an atom per second.

(ii) the number of photoelectrons emitted per second if the efficiency of liberation of photoelectrons is 1%.

Q.8 A neutron with kinetic energy 25 eV strikes a stationary deuteron. Find the de Broglie wavelengths of both particles in the frame of their centre of mass.

Q.9 Two identical nonrelativistic particles move at right angles to each other, possessing De Broglie wavelengths, λ_1 & λ_2. Find the De Broglie wavelength of each particle in the frame of their centre of mass.

Q.10 A stationary He^+ ion emitted a photon corresponding to the first line its Lyman series. That photon liberated a photoelectron from a stationary hydrogen atom in the ground state. Find the velocity of the photoelectron.

Q.11 A gas of identical hydrogen like atoms has some atoms in the lowest (ground) energy level A & some atoms in a particular upper (excited) energy level B & there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by the absorbing monochromatic light of photon energy 2.7eV. Subsequently, the atoms emit radiation of only six different photon energies. Some of the emitted photons have energy 2.7 eV. Some have energy more and some have less than 2.7 eV.

(i) Find the principal quantum number of the initially excited level B.

(ii) Find the ionisation energy for the gas atoms.

(iii) Find the maximum and the minimum energies of the emitted photons.

Q.12 A hydrogen atom in ground state absorbs a photon of ultraviolet radiation of wavelength 50 nm. Assuming that the entire photon energy is taken up by the electron, with what kinetic energy will the electron be ejected ?

Q.13 A monochromatic light source of frequency ν illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency (5/6)ν, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength of 1215 Å. Find the work function of the metal and the frequency ν.

Q.14 An energy of 68.0 eV is required to excite a hydrogen like atom from its second Bohr orbit to the third. The nuclear charge Ze. Find the value of Z, the kinetic energy of the electron in the first Bohr orbit and the wavelength of the electro magnetic radiation required to eject the electron from the first Bohr orbit to infinity.

Q.15 A classical model for the hydrogen atom consists of a single electron of mass m_e in circular motion of radius r around the nucleus (proton). Since the electron is accelerated, the atom continuously radiates electromagnetic waves. The total power P radiated by the atom is given by $P = P_0/r^4$ where

$$P_0 = \frac{e^6}{96\pi^3\varepsilon_0{}^3C^3m_e{}^2} \text{ (C = velocity of light)}$$

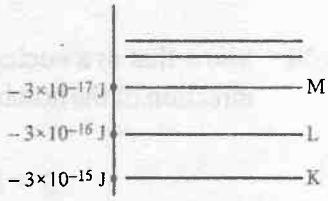
(i) Find the total energy of the atom.

(ii) Calculate an expression for the radius r (t) as a function of time. Assume that at t = 0, the radius is $r_0 = 10^{-10}$ m.

(iii) Hence or otherwise find the time t_0 when the atom collapses in a classical model of the hydrogen atom.

Take : $\left[\frac{2}{\sqrt{3}}\frac{e^2}{4\pi\varepsilon_0}\cdot\frac{1}{m_eC^2} = r_e \approx 3\times10^{-15}\,m\right]$

Q.16 Simplified picture of electron energy levels in a certain atom is shown in the figure. The atom is bombarded with high energy electrons. The impact of one of these electron has caused the complete removal of K-level is filled by an electron from the L-level with a certain amount of energy being released during the transition. This energy may appear as X-ray or may all be used to eject an M-level electron from the atom. Find :



(i) the minimum potential difference through which electron may be accelerated from rest to cause the ejectrion of K-level electron from the atom.

(ii) energy released when L-level electron moves to fill the vacancy in the K-level.

(iii) wavelength of the X-ray emitted. (iv) K.E. of the electron emitted from the M-level.

Q.17 U^{238} and U^{235} occur in nature in an atomic ratio 140 : 1. Assuming that at the time of earth's formation the two isotopes were present in equal amounts. Calculate the age of the earth.
(Half life of $u^{238} = 4.5 \times 10^9$ yrs & that of $U^{235} = 7.13 \times 10^8$ yrs)

Q.18 The kinetic energy of an α – particle which flies out of the nucleus of a Ra^{226} atom in radioactive disintegration is 4.78 MeV. Find the total energy evolved during the escape of the α – particle.

Q.19 A small bottle contains powdered beryllium Be & gaseous radon which is used as a source of α–particles. Neutrons are produced when α–particles of the radon react with beryllium. The yield of this reaction is (1/4000) i.e. only one α–particle out of 4000 induces the reaction. Find the amount of radon (Rn^{222}) originally introduced into the source, if it produces 1.2×10^6 neutrons per second after 7.6 days. [$T_{1/2}$ of R_n = 3.8 days]

Q.20 An experiment is done to determine the half – life of radioactive substance that emits one β–particle for each decay process. Measurement show that an average of 8.4 β are emitted each second by 2.5 mg of the substance. The atomic weight of the substance is 230. Find the half life of the substance.

Q.21 When thermal neutrons (negligible kinetic energy) are used to induce the reaction ;
${}^{10}_{5}B + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He$. α – particles are emitted with an energy of 1.83 MeV.
Given the masses of boron neutron & He^4 as 10.01167, 1.00894 & 4.00386 u respectively. What is the mass of ${}^{7}_{3}Li$? Assume that particles are free to move after the collision.

Q.22 In a fusion reactor the reaction occurs in two stages :

(i) Two deuterium $\left({}_1^2\text{D}\right)$ nuclei fuse to form a tritium $\left({}_1^3\text{T}\right)$ nucleus with a proton as product. The reaction may be represented as D (D, p) T.

(ii) A tritium nucleus fuses with another deuterium nucleus to form a helium $\left({}_2^4\text{He}\right)$ nucleus with neutron as another product. The reaction is represented as T(D , n) α. Find :

(a) The energy release in each stage .

(b) The energy release in the combined reaction per deuterium &

(c) What % of the mass of the initial deuterium is released in the form of energy.

Given : $\left({}_1^2\text{D}\right) = 2.014102$ u ; $\left({}_1^3\text{T}\right) = 3.016049$ u ; $\left({}_2^4\text{He}\right) = 4.002603$ u ;
$\left({}_1^1\text{P}\right) = 1.00785$ u ; $\left({}_0^1\text{n}\right) = 1.008665$ u

Q.23 A wooden piece of great antiquity weighs 50 gm and shows C^{14} activity of 320 disintegrations per minute. Estimate the length of the time which has elapsed since this wood was part of living tree, assuming that living plants show a C^{14} activity of 12 disintegrations per minute per gm. The half life of C^{14} is 5730 yrs.

Q.24 Show that in a nuclear reaction where the outgoing particle is scattered at an angle of 90° with the direction of the bombarding particle, the Q-value is expressed as

$$Q = K_P\left(1+\frac{m_P}{M_O}\right) - K_I\left(1+\frac{m_I}{M_O}\right)$$

Where, I = incoming particle, P = product nucleus, T = target nucleus, O = outgoing particle.

Q.25 When Lithium is bombarded by 10 MeV deutrons, neutrons are observed to emerge at right angle to the direction of incident beam. Calculate the energy of these neutrons and energy and angle of recoil of the associated Beryllium atom. Given that : m $({}_0n^1)$ = 1.00893 amu ; m $({}_3Li^7)$ = 7.01784 amu ; m $({}_1H^2)$ = 2.01472 amu ; and m $({}_4Be^8)$ = 8.00776 amu.

Q.26 A body of mass m_0 is placed on a smooth horizontal surface. The mass of the body is decreasing exponentially with disintegration constant λ. Assuming that the mass is ejected backward with a relative velocity v. Initially the body was at rest. Find the velocity of body after time t.

Q.27 A radionuclide with disintegration constant λ is produced in a reactor at a constant rate α nuclei per sec. During each decay energy E_0 is released. 20% of this energy is utilised in increasing the temperature of water. Find the increase in temperature of m mass of water in time t. Specific heat of water is S. Assume that there is no loss of energy through water surface.

EXERCISE # III

Q.1 A neutron of kinetic energy 65 eV collides inelastically with a singly ionized helium atom at rest. It is scattered at an angle of 90° with respect of its original direction.

(i) Find the allowed values of the energy of the neutron & that of the atom after collision.

(ii) If the atom gets de-excited subsequently by emitting radiation, find the frequencies of the emitted radiation. (Given : Mass of he atom = 4×(mass of neutron), ionization energy of H atom = 13.6 eV) [JEE '93]

Q.2 A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 eV & 17.00 eV respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV & 5.95 eV respectively. Determine the values of n & Z. (Ionisation energy of hydrogen atom = 13.6 eV) [JEE'94]

Q.3 Select the correct alternative(s) :
When photons of energy 4.25 eV strike the surface of a metal A, the ejected photo electrons have maximum kinetic energy T_A eV and de-Broglie wave length γ_A. The maximum kinetic energy of photo electrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50)$ eV. If the de-Broglie wave length of these photo electrons is $\gamma_B = 2\gamma_A$, then :

(A) the work function of A is 2.225 eV
(B) the work function of B is 4.20 eV
(C) $T_A = 2.00$ eV
(D) $T_B = 2.75$ eV [JEE'94]

Q.4 In a photo electric effect set-up, a point source of light of power 3.2×10^{-3} W emits mono energetic photons of energy 5.0 eV. The source is located at a distance of 0.8 m from the centre of a stationary metallic sphere of work function 3.0 eV & of radius 8.0×10^{-3}m. The efficiency of photo electrons emission is one for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral, and that photo electrons are instantly swept away after emission.

(a) Calculate the number of photo electrons emitted per second.

(b) Find the ratio of the wavelength of incident light to the De - Broglie wave length of the fastest photo electrons emitted.

(c) It is observed that the photo electron emission stops at a certain time t after the light source is switched on. Why ?

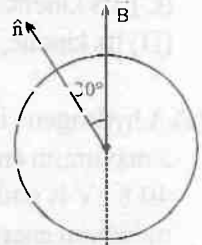
(d) Evaluate the time t. [JEE'95]

Q.5 An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (In eV) required to remove both the electrons form a neutral helium atom is :

(A) 38.2 (B) 49.2 (C) 51.8 (D) 79.0 [JEE'95]

Q.6 An electron, in a hydrogen like atom, is in an excited state. It has a total energy of − 3.4 eV. Calculate: (i) The kinetic energy & (ii) The De - Broglie wave length of the electron. [JEE 96]

Q.7 An electron in the ground state of hydrogen atoms is revolving in anti-clockwise direction in a circular orbit of radius R.



(i) Obtain an expression for the orbital magnetic dipole moment of the electron.

(ii) The atom is placed in a uniform magnetic induction, such that the plane normal to the electron orbit make an angle of 30° with the magnetic induction. Find the torque experienced by the orbiting electron. [JEE'96]

Q.8 A potential difference of 20 KV is applied across an x-ray tube. The minimum wave length of X - rays generated is ________ . [JEE'96]

Q.9(i) As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom (Z = 3) is
(A) 1.51 (B) 13.6 (C) 40.8 (D) 122.4

(ii) Assume that the de-Broglie wave associated with an electron can form a standing wave between the atoms arranged in a one dimensional array with nodes at each of the atomic sites. It is found that one such standing wave is formed if the distance 'd' between the atoms of the array is 2 Å. A similar standing wave is again formed if 'd' is increased to 2.5 Å but not for any intermediate value of d. Find the energy of the electrons in electron volts and the least value of d for which the standing wave of the type described above can form. [JEE' 97]

Q.10(i) The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately :
(A) 540 nm (B) 400 nm (C) 310 nm (D) 220 nm

(ii) The electron in a hydrogen atom makes a transition $n_1 \longrightarrow n_2$, where n_1 & n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 & n_2 are :
(A) $n_1 = 4, n_2 = 2$ (B) $n_1 = 8, n_2 = 2$
(C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 6, n_2 = 3$ [JEE '98]

Q.11 A particle of mass M at rest decays into two particles of masses m_1 and m_2, having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles, λ_1/λ_2, is
(A) m_1/m_2 (B) m_2/m_1 (C) 1.0 (D) $\sqrt{m_2}/\sqrt{m_1}$ [JEE '99]

Q.12 Photoelectrons are emitted when 400 nm radiation is incident on a surface of work function 1.9eV. These photoelectrons pass through a region containing α-particles. A maximum energy electron combines with an α-particle to form a He^+ ion, emitting a single photon in this process. He^+ ions thus formed are in their fourth excited state. Find the energies in eV of the photons, lying in the 2 to 4eV range, that are likely to be emitted during and after the combination. [Take, $h = 4.14 \times 10^{-15}$ eV–s] [JEE '99]

Q.13(a) Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to
(A) 9/(5R) (B) 36/(5R) (C) 18/(5R) (D) 4/R [JEE' 2000 (Scr)]

(b) The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true?
(A) Its kinetic energy increases and its potential and total energies decrease.
(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same.
(C) Its kinetic and total energies decrease and its potential energy increases.
(D) Its kinetic, potential and total energies decrease. [JEE' 2000 (Scr)]

Q.14(a) A hydrogen - like atom of atomic number Z is in an excited state of quantum number 2 n. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. Find n, Z and the ground state energy (in eV) for this atom. Also, calculate the minimum energy (in eV) that can be emitted by this atom during de-excitation. Ground state energy of hydrogen atom is – 13.6 eV. [JEE' 2000]

(b) When a beam of 10.6 eV photon of intensity 2 W/m² falls on a platinum surface of area 1×10^4 m² and work function 5.6 ev, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per sec and their minimum and maximum energies in eV. [JEE' 2000]

Q.15 The potential difference applied to an X - ray tube is 5 kV and the current through it is 3.2 mA. Then the number of electrons striking the target per second is [JEE' 2002 (Scr.)]

(A) 2×10^{16} (B) 5×10^{16} (C) 1×10^{17} (D) 4×10^{15}

Q.16 A Hydrogen atom and Li^{++} ion are both in the second excited state. If l_H and l_{Li} are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then

(A) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$ (B) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$

(C) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$ (D) $l_H < l_{Li}$ and $|E_H| < |E_{Li}|$ [JEE 2002 (Scr)]

Q.17 A hydrogen like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transition between a group of levels. These levels have energies between – 0.85 eV and – 0.544 eV (including both these values)

(a) Find the atomic number of the atom.

(b) Calculate the smallest wavelength emitted in these transitions. [JEE' 2002]

Q.18 Two metallic plates A and B each of area 5×10^{-4} m^2, are placed at a separation of 1 cm. Plate B carries a positive charge of 33.7×10^{-12} C. A monochromatic beam of light, with photons of energy 5 eV each, starts falling on plate A at t = 0 so that 10^{16} photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10^6 incident photons. Also assume that all the emitted photoelectrons are collected by plate B and the work function of plate A remains constant at the value 2 eV. Determine

(a) the number of photoelectrons emitted up to t = 10 sec.

(b) the magnitude of the electric field between the plates A and B at t = 10 s and

(c) the kinetic energy of the most energetic photoelectron emitted at t = 10 s when it reaches plate B. (Neglect the time taken by photoelectron to reach plate B) [JEE' 2002]

Q.19 The attractive potential for an atom is given by $v = v_0 \ln(r / r_0)$, v_0 and r_0 are constant and r is the radius of the orbit. The radius r of the nth Bohr's orbit depends upon principal quantum number n as :

(A) $r \propto n$ (B) $r \propto 1/n^2$ (C) $r \propto n^2$ (D) $r \propto 1/n$

[JEE' 2003 (Scr)]

Q.20 Frequency of a photon emitted due to transition of electron of a certain elemrnt from L to K shell is found to be 4.2×10^{18} Hz. Using Moseley's law, find the atomic number of the element, given that the Rydberg's constant $R = 1.1 \times 10^7$ m^{-1}. [JEE' 2003]

Q.21 In a photoelctric experiment set up, photons of energy 5 eV falls on the cathode having work function 3 eV

(a) If the saturation current is $i_A = 4\mu A$ for intensity 10^{-5} W/m^2, then plot a graph between anode potential and current.

(b) Also draw a graph for intensity of incident radiation of 2×10^{-5} W/m^2 ? [JEE' 2003]

Q.22 A star initially has 10^{40} deutrons. It produces energy via, the processes $_1H^2 + {_1H^2} \rightarrow {_1H^3} + p$ & $_1H^2 + {_1H^3} \rightarrow {_2He^4} + n$. If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of : [JEE '93]

(A) 10^6 sec (B) 10^8 sec (C) 10^{12} sec (D) 10^{16} sec

Q.23 A small quantity of solution containing ^{24}Na radionuclide (half life 15 hours) of activity 1.0 microcurie is injected into the blood of a person. A sample of the blood of volume 1 cm^3 taken after 5 hours shows an activity of 296 disintegrations per minute. Determine the total volume of blood in the body of the person. Assume that the radioactive solution mixes uniformly in the blood of the person. (1 Curie = 3.7×10^{10} disintegrations per second) [JEE'94]

Q.24(i) Fast neutrons can easily be slowed down by :

(A) the use of lead shielding (B) passing them through water

(C) elastic collisions with heavy nuclei (D) applying a strong electric field

(ii) Consider α – particles, β – particles & γ rays, each having an energy of 0.5 MeV. Increasing order of penetrating powers, the radiations are : [JEE'94]
(A) α, β, γ (B) α, γ, β (C) β, γ, α (D) γ, β, α

Q.25 Which of the following statement(s) is (are) correct? [JEE'94]
(A) The rest mass of a stable nucleus is less than the sum of the rest masses of its separated nucleons.
(B) The rest mass of a stable nucleus is greater than the sum of the rest masses of its separated nucleons.
(C) In nuclear fusion, energy is released by fusion two nuclei of medium mass (approximately 100 amu).
(D) In nuclear fission, energy is released by fragmentation of a very heavy nucleus.

Q.26 The binding energy per nucleon of ^{16}O is 7.97 MeV & that of ^{17}O is 7.75 MeV. The energy in MeV required to remove a neutron from ^{17}O is : [JEE'95]
(A) 3.52 (B) 3.64 (C) 4.23 (D) 7.86

Q.27 At a given instant there are 25 % undecayed radio – active nuclei in a sample. After 10 sec the number of undecayed nuclei remains to 12.5 %. Calculate : [JEE 96]
(i) mean – life of the nuclei and
(ii) The time in which the number of undecayed nuclear will further reduce to 6.25 % of the reduced number.

Q.28 Consider the following reaction ; $^2H_1 + ^2H_1 = ^4He_2 + Q$. [JEE 96]
Mass of the deuterium atom = 2.0141 u ; Mass of the helium atom = 4.0024 u
This is a nuclear ________ reaction in which the energy Q is released is ________ MeV.

Q.29(a) The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV The stopping potential in Volts is :
(A) 2 (B) 4 (C) 6 (D) 10

(b) In the following, **column I** lists some physical quantities & the **column II** gives approx. energy values associated with some of them. Choose the appropriate value of energy from **column II** for each of the physical quantities in **column I** and write the corresponding letter A, B, C etc. against the number (i), (ii), (iii), etc. of the physical quantity in the answer book. In your answer, the sequence of **column I** should be maintained.

Column I	**Column II**
(i) Energy of thermal neutrons	(A) 0.025 eV
(ii) Energy of X–rays	(B) 0.5 eV
(iii) Binding energy per nucleon	(C) 3 eV
(iv) Photoelectric threshold of metal	(D) 20 eV
	(E) 10 keV
	(F) 8 MeV

(c) The element Curium $^{248}_{96}Cm$ has a mean life of 10^{13} seconds. Its primary decay modes are spontaneous fission and α decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α decay are as follows :
$^{248}_{96}Cm$=248.072220u, $^{244}_{94}Pu$=244.064100u & ^4_2He =4.002603 u.
Calculate the power output from a sample of 10^{20} Cm atoms. ($1 u = 931 MeV/c^2$) [JEE'97]

Q.30 Select the correct alternative(s). [JEE '98]
(i) Let m_p be the mass of a proton, m_n the mass of a neutron, M_1 the mass of a $^{20}_{10}Ne$ nucleus & M_2 the mass of a $^{40}_{20}Ca$ nucleus. Then :
(A) $M_2 = 2 M_1$ (B) $M_2 > 2 M_1$ (C) $M_2 < 2 M_1$ (D) $M_1 < 10 (m_n + m_p)$

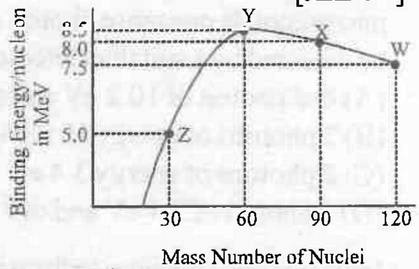
(ii) The half – life of ^{131}I is 8 days. Given a sample of ^{131}I at time t = 0, we can assert that :
(A) no nucleus will decay before t = 4 days (B) no nucleus will decay before t = 8 days
(C) all nuclei will decay before t = 16 days (D) a given nucleus may decay at any time after t = 0.

Q.31 Nuclei of a radioactive element A are being produced at a constant rate α. The element has a decay constant λ. At time t = 0, there are N_0 nuclei of the element.

(a) Calculate the number N of nuclei of A at time t.

(b) If $\alpha = 2N_0\lambda$, calculate the number of nuclei of A after one halflife of A & also the limiting value of N as $t \to \infty$. [JEE '98]

Q.32(a) Binding energy per nucleon vs. mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is



(A) $Y \to 2Z$ (B) $W \to X + Z$
(C) $W \to 2Y$ (D) $X \to Y + Z$

(b) Order of magnitude of density of Uranium nucleus is, $[m_P = 1.67 \times 10^{-27}$ kg]
(A) 10^{20} kg/m³ (B) 10^{17}kg/m³ (C) 10^{14}kg/m³ (D) 10^{11}kg/m³

(c) ^{22}Ne nucleus, after absorbing energy, decays into two α–particles and an unknown nucleus. The unknown nucleus is
(A) nitrogen (B) carbon (C) boron (D) oxygen

(d) Which of the following is a correct statement?
(A) Beta rays are same as cathode rays
(B) Gamma rays are high energy neutrons.
(C) Alpha particles are singly ionized helium atoms
(D) Protons and neutrons have exactly the same mass
(E) None

(e) The half–life period of a radioactive element X is same as the mean–life time of another radioactive element Y. Initially both of them have the same number of atoms. Then
(A) X & Y have the same decay rate initially (B) X & Y decay at the same rate always
(C) Y will decay at a faster rate than X (D) X will decay at a faster rate than Y [JEE '99]

Q.33 Two radioactive materials X_1 and X_2 have decay constants 10λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that of X_2 will be 1/e after a time
(A) $1/(10\lambda)$ (B) $1/(11\lambda)$ (C) $11/(10\lambda)$ (D) $1/(9\lambda)$ [JEE '2000 (Scr)]

Q.34 The electron emitted in beta radiation originates from [JEE'2001(Scr)]
(A) inner orbits of atoms (B) free electrons existing in nuclei
(C) decay of a neutron in a nucleus (D) photon escaping from the nucleus

Q.35 The half - life of ^{215}At is 100 μs. The time taken for the radioactivity of a sample of ^{215}At to decay to 1/16th of its initial value is [JEE 2002 (Scr)]
(A) 400 μs (B) 6.3 μs (C) 40 μs (D) 300 μs

Q.36 Which of the following processes represents a gamma - decay? [JEE 2002 (Scr)]
(A) $^AX_Z + \gamma \longrightarrow {}^AX_{Z-1} + a + b$ (B) $^AX_Z + {}^1n_0 \longrightarrow {}^{A-3}X_{Z-2} + c$
(C) $^AX_Z \longrightarrow {}^AX_Z + f$ (D) $^AX_Z + e_{-1} \longrightarrow {}^AX_{Z-1} + g$

Q.37 The volume and mass of a nucleus are related as [JEE 2003 (Scr)]
(A) $v \propto m$ (B) $v \propto 1/m$ (C) $v \propto m^2$ (D) $v \propto 1/m^2$

Q.38 The nucleus of element X (A = 220) undergoes α-decay. If Q-value of the reaction is 5.5 MeV, then the kinetic energy of α-particle is : [JEE 2003 (Scr)]
(A) 5.4 MeV (B) 10.8 MeV (C) 2.7 MeV (D) None

Q.39 A radioactive sample emits n β-particles in 2 sec. In next 2 sec it emits 0.75 n β-particles, what is the mean life of the sample? [JEE 2003]

Q.40 The wavelength of K_α X-ray of an element having atomic number z = 11 is λ. The wavelength of K_α X-ray of another element of atomic number z' is 4λ. Then z' is
(A) 11 (B) 44 (C) 6 (D) 4 [JEE' 2005 (Scr)]

Q.41 A photon of 10.2 eV energy collides with a hydrogen atom in ground state inelastically. After few microseconds one more photon of energy 15 eV collides with the same hydrogen atom. Then what can be detected by a suitable detector.
(A) one photon of 10.2 eV and an electron of energy 1.4 eV
(B) 2 photons of energy 10.2 eV
(C) 2 photons of energy 3.4 eV
(D) 1 photon of 3.4 eV and one electron of 1.4 eV [JEE' 2005 (Scr)]

Q.42 Helium nuclie combines to form an oxygen nucleus. The binding energy per nucleon of oxygen nucleus is if $m_0 = 15.834$ amu and $m_{He} = 4.0026$ amu
(A) 10.24 MeV (B) 0 MeV (C) 5.24 MeV (D) 4 MeV
[JEE' 2005 (Scr)]

Q.43 The potential energy of a particle of mass m is given by

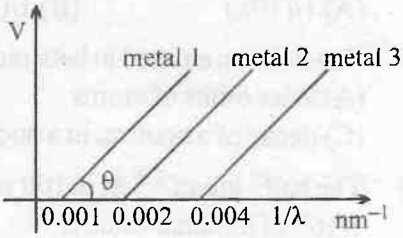
$$V(x) = \begin{cases} E_0 & 0 \le x \le 1 \\ 0 & x > 1 \end{cases}$$

λ_1 and λ_2 are the de-Broglie wavelengths of the particle, when $0 \le x \le 1$ and $x > 1$ respectively. If the total energy of particle is $2E_0$, find λ_1/λ_2. [JEE 2005]

Q.44 Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of nucleus to that of helium nucleus is $(14)^{1/3}$. Find
(a) atomic number of the nucleus
(b) the frequency of K_α line of the X-ray produced. ($R = 1.1 \times 10^7\ m^{-1}$ and $c = 3 \times 10^8$ m/s)
[JEE 2005]

Q.45 Given a sample of Radium-226 having half-life of 4 days. Find the probability, a nucleus disintegrates within 2 half lives.
(A) 1 (B) 1/2 (C) 3/4 (D) 1/4 [JEE 2006]

Q.46 The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photo-electric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct? [Here λ is the wavelength of the incident ray].



(A) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$
(B) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$
(C) $\tan\theta$ is directly proportional to hc/e, where h is Planck's constant and c is the speed of light
(D) The violet colour light can eject photoelectrons from metals 2 and 3. [JEE 2006]

Q.47 In hydrogen-like atom (z = 11), n^{th} line of Lyman series has wavelength λ equal to the de-Broglie's wavelength of electron in the level from which it originated. What is the value of n? [JEE 2006]

Q.48 Match the following Columns [JEE 2006]

Column 1	Column 2
(A) Nuclear fusion	(P) Converts some matter into energy
(B) Nuclear fission	(Q) Generally occurs for nuclei with low atomic number
(C) β–decay	(R) Generally occurs for nuclei with higher atomic number
(D) Exothermic nuclear reaction	(S) Essentially proceeds by weak nuclear forces

ANSWER KEY

EXERCISE # I

Q.1 885 Q.2 (a) 2.25eV, (b) 4.2eV, (c) 2.0 eV, 0.5 eV Q.3 (a) 0.6 volt, (b) 2.0 mA

Q.4 when the potential is steady, photo electric emission just stop when $h\upsilon = (3 + 1)eV = 4.0$ eV

Q.5 5.76×10^{-11} A Q.6 15/8 V Q.7 487.06 nm Q.8 4.26 m/s, 13.2 eV

Q.9 7 : 36 Q.10 22.8 nm Q.11 $\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$ Q.12 18/(5R)

Q.13 1.257×10^{-23} Am^2 Q.14 2.48×10^{-12} m Q.15 $\frac{5}{16}, \frac{10^{20}}{80\pi}$ Q.16 2 eV, 6.53×10^{-34} J-s

Q.17 5 Q.18 (i) 5, 16.5 eV, 36.4 A, 340 eV, – 680 eV, $\frac{h}{2\pi}$ 1.06×10^{-11} m

Q.19 z = 3, n = 7 Q.20 54.4 eV Q.21 n = 3, 3 : 1 Q.22 23.6 MeV

Q.23 ($T_{1/2}$ = 10.8 sec) Q.24 (i) ${}^{40}_{19}K \longrightarrow {}^{40}_{18}Ar + {}_{+1}e^0 + \nu$ (ii) 4.2×10^9 years

Q.25 $t = \left(\frac{ln 5}{ln 2}\right)\tau$ Q.26 $8/3 \times 10^{18}$ sec Q.27 1.14×10^{18} sec Q.28 $-h/eEt^2$

EXERCISE # II

Q.1 8IhR/3C $\frac{38IRh}{15C}$ Q.2 4.8×10^{16}, 4.0 cm Q.3 1.99 eV, 0.760 V

Q.4 1.1×10^{12} Q.5 (i) 4125Å, (ii) 13.2 µA

Q.6 (i) 1.33×10^{16} photons/m^2 – s ; 0.096 µÅ (ii) 2.956×10^{15} photons/m^{2}s ; 0.0213 µA (iii) 1.06 volt

Q.7 (i) 5/16 photon/sec, (ii) 5/1600 electrons/sec Q.8 $\lambda_{deutron} = \lambda_{neutron} = 8.6$ pm

Q.9 $\lambda = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$ Q.10 3.1×10^6 m/s Q.11 (i) 2 ; (ii) 23.04×10^{-19}J ; (iii) $4 \rightarrow 1$, $4 \rightarrow 3$

Q.12 11.24 eV Q.13 6.8 eV, 5×10^{15} Hz Q.14 489.6 eV, 25.28 Å

Q.15 (i) $-\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$, (ii) $r_0\left(1-\frac{3Cr_e^2t}{r_0^3}\right)^{1/3}$, (iii) $10^{-10} \times \frac{100}{81}$ sec

Q.16 (i) 1.875×10^4 V, (ii) 2.7×10^{-15} J, (iii) 0.737 Å, (iv) 2.67×10^{-15} J

Q.17 6.04×10^9 yrs Q.18 4.87 MeV Q.19 3.3×10^{-6} g

Q.20 1.7×10^{10} years Q.21 7.01366 amu

Q.22 (a) 4 MeV , 17.6 (b) 7.2 MeV (c) 0.384 % Q.23 5196 yrs

Q.25 Energy of neutron = 19.768 MeV ; Energy of Beryllium = 5.0007 MeV;
Angle of recoil = $\tan^{-1}(1.034)$ or 46°

Q.26 $v = u\lambda t$ Q.27 $\Delta T = \frac{0.2E_f\left[\alpha t - \frac{\alpha}{\lambda}(1-e^{-\lambda t})\right]}{mS}$

EXERCISE # III

Q.1 (i) Allowed values of energy of neutron = 6.36 eV and 0.312 eV ; Allowed values of energy of He atom = 17.84 eV and 16.328 eV , (ii) 18.23×10^{15} Hz , 9.846×10^{15} Hz , 11.6×10^{15} Hz

Q.2 n = 6, Z = 3 Q.3 B, C Q.4 (a) $10^5\ s^{-1}$; (b) 286.18 ; (d) 111 s

Q.5 D Q.6 (i) KE = 3.4 eV, (ii) λ = 6.66 Å Q.7 (i) $\frac{he}{4\pi m}$ (ii) $\frac{ehB}{8\pi m}$

Q.8 0.61 Å Q.9 (i) D, (ii) KE $\cong$ 151 eV, d_{least} = 0.5 Å

Q.10 (i) C (ii) A, D Q.11 C

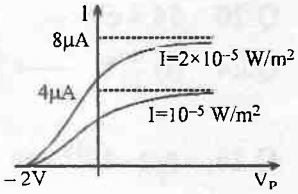
Q.12 during combination = 3.365 eV; after combination = 3.88 eV $(5 \rightarrow 3)$ & 2.63 eV $(4 \rightarrow 3)$

Q.13 (a) C, (b) A

Q.14 (a) n = 2, z = 4; G.S.E. – 217.6 eV; Min. energy = 10.58 eV; (b) 6.25×10^{19} per sec, 0, 5 eV

Q.15 A Q.16 B Q.17 3, 4052.3 nm Q.18 5×10^7, 2000N/C, 23 eV

Q.19 A Q.20 z = 42 Q.21



Q.22 C Q.23 6 litre Q.24 (i) B, (ii) A Q.25 A , D

Q.26 C Q.27 (i) $t_{1/2}$ = 10 sec. , t_{means} = 14.43 s (ii) 40 seconds

Q.28 Fusion , 24 Q.29 (a) B, (b) (i) – A, (ii) – E, (iii) – F, (iv) – C, (c) $\cong$ 33.298 μW

Q.30 (i) C, D (ii) D Q.31 (a) $N = \frac{1}{\lambda}[\alpha(1 - e^{-\lambda t}) + \lambda N_0 e^{-\lambda t}]$ (b) $\frac{3N_0}{2}$, $2N_0$

Q.32 (a) C ; (b) B ; (c) B ; (d) E ; (e) C Q.33 D

Q.34 C Q.35 A Q.36 C Q.37 A

Q.38 A Q.39 $1.75n = N_0(1 - e^{-4\lambda})$, 6.95 sec, $\frac{2}{ln\left(\frac{4}{3}\right)}$ Q.40 C

Q.41 A Q.42 A Q.43 $\sqrt{2}$ Q.44 $\nu = 1.546 \times 10^{18}$ Hz

Q.45 C Q.46 A,C Q.47 n = 24

Q.48 (A) P, Q; (B) P, R; (C) S, P; (D) P, Q, R

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (P, Q, R, S)

PARTICLE DYNAMICS

CONTENTS

KEY CONCEPT

FORCE

1. There are, basically, five forces, which are commonly encountered in mechanics.

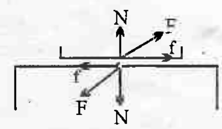
(i) **Weight :** Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

$$W = \frac{GMm}{R^2} = mg$$

(ii) **Contact Force :** When two bodies come in contact they exert forces on each other that is called contact forces.

(a) **Normal force (N) :** It is the component of contact force normal to the surface. It measures how strongly the surfaces in contact are pressed together.

(b) **Frictional force :** It is the component of contact force parallel to the surface. It opposes the relative motion (or attempted motion) of the two surfaces in contact.



(iii) **Tension :** The force exerted by the end of a taut string, rope or chain is called the tension. The direction of tension is to pull the body while that of normal reaction is to push the body.

(iv) **Spring force :** The force exerted by a spring is given by $F = -kx$, where x is the change in length and k is the stiffness constant or spring constant (units Nm^{-1}).

NEWTON'S LAWS

2. **Newton's First Law :** Every particle continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by the action of an applied force.

3. **Newton's Second Law :** $\vec{F}_{net} = m\vec{a}$

4. **Newton's Third Law :** Whenever two bodies interact they exert forces on each other which are equal in magnitude and opposite in direction. So whenever body A exerts a force F on body B, B exerts a force – F on A.

Inertial Reference Frame : A reference frame in which Newton's first law is valid is called an inertial reference frame. An inertial frame is either at rest or moving with uniform velocity.

Non-Inertial Frame : An accelerated frame of reference is called a non-inertial frame. Objects in non-inertial frames do not obey Newton's first law.

Pseudo Force : It is an imaginary force which is recognized only by a non-inertial observer to explain the physical situation according to Newton's law The magnitude of this force F_P is equal to the product of the mass m of the object and acceleration a of the frame of reference. The direction of the force is opposite to the direction of acceleration.

$$F_P = -ma$$

The **force of friction** comes into action only when there is a relative motion between the two contact surfaces or when an attempt is made to have it.

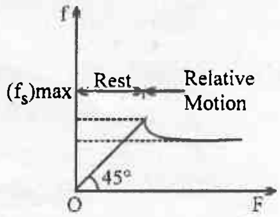
The force of friction on each body is in a direction opposite to its motion (existing or impending) relative to other body.

5. **Static friction :** The frictional force acting between any two surfaces at rest with respect to each other is called the force of static friction (f_s).

$$f_s \le \mu_s N$$

where μ_s is the static coefficient of friction.

6. **Kinetic friction :** The frictional force acting between surfaces in relative motion with respect to each other is called the force of kinetic friction or sliding friction (f_k).

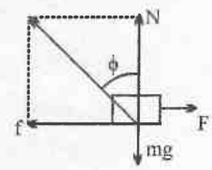


$$f_k = \mu_k N$$

where μ_k is the coefficient of kinetic friction.

$$\mu_s > \mu_k$$

Angle of friction (ϕ) : Mathematically, the angle of friction (ϕ) may be defined as the angle between the normal reaction N and the resultant of the maximum friction force f and the normal reaction.



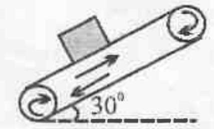
Thus $\tan\phi = \dfrac{f}{N}$

Since $f = \mu N$, therefore,

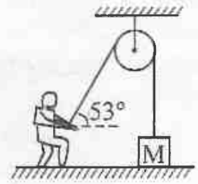
$$\tan \phi = \mu$$

(NEWTONS LAW FORCE & FRICTION)
EXERCISE–I

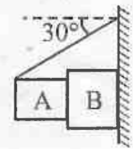
Q.1 A block of mass 1 kg is stationary with respect to a conveyor belt that is accelerating with 1 m/s^2 upwards at an angle of 30° as shown in figure. Determine force of friction on block and contact force between the block & bell.



Q.2 A man of mass 63 kg is pulling a mass M by an inextensible light rope passing through a smooth and massless pulley as shown in figure. The coefficient of friction between the man and the ground is $\mu = 3/5$. Find the maximum value of M that can be pulled by the man without slipping on the ground.



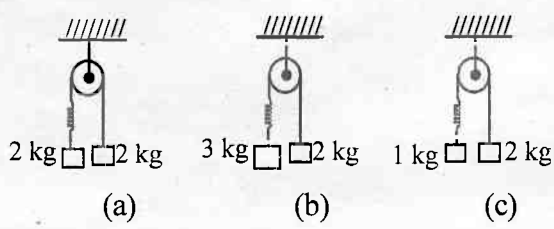
Q.3 Two blocks A and B of mass m 10 kg and 20 kg respectively are placed as shown in figure. Coefficient of friction between all the surfaces is 0.2. Then find tension in string and acceleration of block B. ($g = 10$ m/s^2)



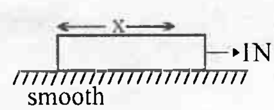
Q.4 An inclined plane makes an angle 30° with the horizontal. A groove OA = 5 m cut in the plane makes an angle 30° with OX. A short smooth cylinder is free to slide down the influence of gravity. Find the time taken by the cylinder to reach from A to O. ($g = 10$ m/s^2)



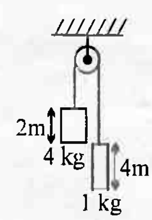
Q.5 Same spring is attached with 2 kg, 3 kg and 1 kg blocks in three different cases as shown in figure. If x_1, x_2 and x_3 be the constan extensions in the spring in these three cases then find the ratio of their extensions.



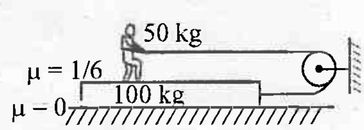
Q.6 A rope of length L has its mass per unit length λ varies according to the function $\lambda(x) = e^{x/L}$. The rope is pulled by a constant force of 1N on a smooth horizontal surface. Find the tension in the rope at $x = L/2$.



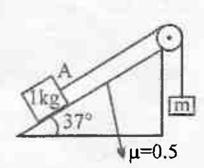
Q.7 In figure shown, both blocks are released from rest. Find the time to cross each other?



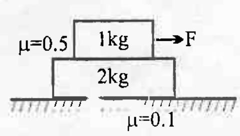
Q.8 A man of mass 50 kg is pulling on a plank of mass 100 kg kept on a smooth floor as shown with force of 100 N. If both man & plank move together, find force of friction acting on man.



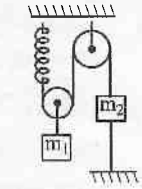
Q.9 In the figure, what should be mass m so that block A slide up with a constant velocity?



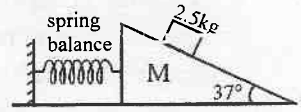
Q.10 What should be minimum value of F so that 2 kg slides on ground but 1 kg does not slide on it? [$g = 10$ m/sec^2]



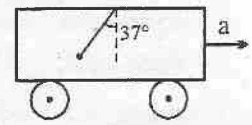
Q.11 In figure shown, pulleys are ideal $m_1 > 2\,m_2$. Initially the system is in equilibrium and string connecting m_2 to rigid support below is cut. Find the initial acceleration of m_2?



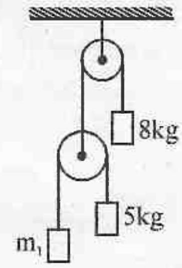
Q.12 Find the reading of spring balance as shown in figure. Assume that mass M is in equilibrium



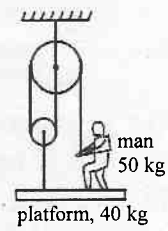
Q.13 At what acceleration of the trolley will the string makes an angle of 37° with vertical if a small mass is attached to bottom of string.



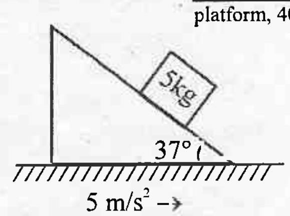
Q.14 At what value of m_1 will 8 kg mass be at rest.



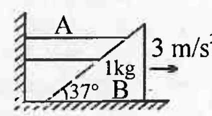
Q.15 What force must man exert on rope to keep platform in equilibrium?



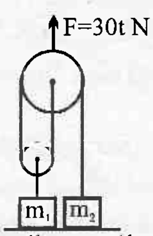
Q.16 Inclined plane is moved towards right with an acceleration of 5 ms^{-2} as shown in figure. Find force in newton which block of mass 5 kg exerts on the incline plane.



Q.17 Find force in newton which mass A exerts on mass B if B is moving towards right with 3 ms^{-2}.



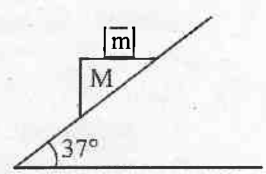
Q.18 Force F is applied on upper pulley. If F = 30t where t is time in second. Find the time when m_1 loses contact with floor.



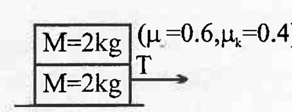
m_1=4kg, m_2=1kg

Q.19 A block of mass 1 kg is horizontally thrown with a velocity of 10 m/s on a stationary long plank of mass 2 kg whose surface has a $\mu = 0.5$. Plank rests on frictionless surface. Find the time when m_1 comes to rest w.r.t. plank.

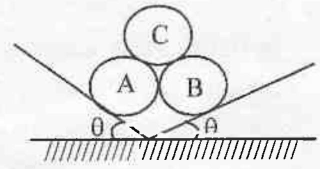
Q.20 Block M slides down on frictionless incline as shown. Find the minimum friction coefficient so that m does not slide with respect to M.



Q.21 The coefficient of static and kinetic friction between the two blocks and also between the lower block and the ground are $\mu_s = 0.6$ and $\mu_k = 0.4$. Find the value of tension T applied on the lower block at which the upper block begins to slip relative to lower block.



Q.22 Three identical rigid circular cylinders A, B and C are arranged on smooth inclined surfaces as shown in figure. Find the least value of θ that prevent the arrangement from collapse.



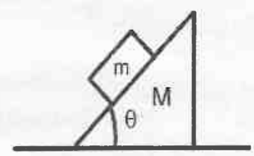
Q.23 Two men A and B of equal mass held on to the free ends of a massless rope which passes over a frictionless light pulley. Man A climbs up the rope with acceleration *a* relative to the rope while man B hangs on without climbing. Find the acceleration of the man B with respect to ground.

Q.24 A thin rod of length 1 m is fixed in a vertical position inside a train, which is moving horizontally with constant acceleration 4 m/s^2. A bead can slide on the rod, and friction coefficient between them is 1/2. If the bead is released from rest at the top of the rod, find the time when it will reach at the bottom.

Q.25 A body of mass M = 5kg rests on a horizontal plane having coefficient of fiction $\mu = 0.5$. At t = 0 a horizontal force F is applied that varies with time as F = 5t. Find the time instant t_0 at which motion starts and also find the distance of particle from starting point at t = 6 second.

EXERCISE–II

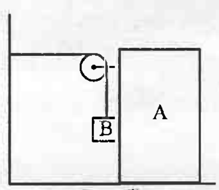
Q.1 A block of mass m lies on wedge of mass M as shown in figure. Answer following parts separately.



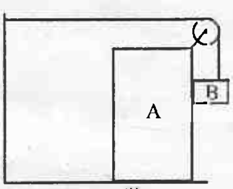
(a) With what minimum acceleration must the wedge be moved towards right horizontally so that block m falls freely.

(b) Find the minimum friction coefficient required between wedge M and ground so that it does not move while block m slips down on it.

Q.2 A 20 kg block B is suspended from a cord attached to a 40 kg cart A. Find the ratio of the acceleration of the block in cases (i) & (ii) shown in figure immediately after the system is released from rest. (neglect friction)

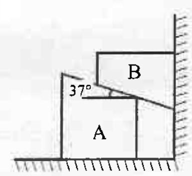


Case (i)

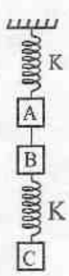


Case (ii)

Q.3 The masses of blocks A and B are same and equal to m. Friction is absent everywhere. Find the normal force with which block B presses on the wall and accelerations of the blocks A and B.



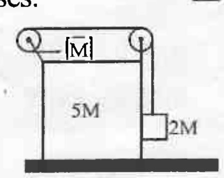
Q.4 The system shown adjacent is in equilibrium. Find the acceleration of the blocks A, B & C all of equal masses m at the instant when (Assume springs to be ideal)



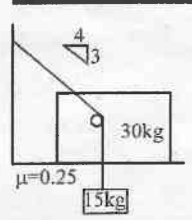
(a) The spring between ceiling & A is cut.
(b) The string (inextensible) between A & B is cut.
(c) The spring between B & C is cut.

Also find the tension in the string when the system is at rest and in the above 3 cases.

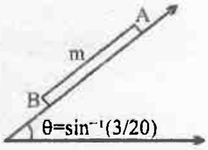
Q.5 In the system shown. Find the initial acceleration of the wedge of mass 5M. The pulleys are ideal and the cords are inextensible. (there is no friction anywhere).



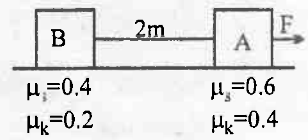
Q.6 The system is released from rest in the position shown. Calculate the tension T in the cord and the acceleration a of the 30 kg block in the position shown. The small pulley attached to the block has negligible mass and friction.



Q.7 A plank of mass m is kept on a smooth inclined plane. A man of mass η times the mass of plank moves on the plank, starts from A, such that the plank is at rest, w.r.t. the inclined plane. If he reaches the other end B of the plank in t = 5sec. Then find the acceleration & the value of η, if the length of the plank is 50m.

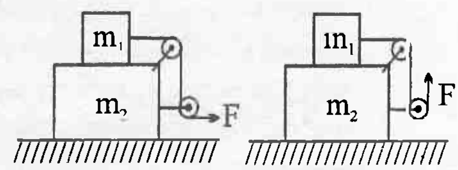


Q.8 Two horizontal blocks each of mass 1/2 kg are connected by a massless, inextensible string of length 2m and placed on a long horizontal table. The coefficient of static & kinetic friction are shown in the figure. Initially the blocks are at rest. If the leading block is pulled with a time dependent horizontal force $F = kt\,\hat{i}$ where k=1N/sec., determine



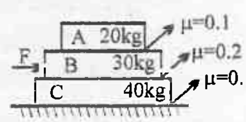
(a) The plots of acceleration of each block with time from t = 0 to t = 10sec.
(b) Velocity of blocks at t = 10sec.
(c) Distance transversed by the blocks in the time interval t = 0 to t = 10sec.
(d) If F stops acting at t = 10sec. find after how much further time would B collide with A.

Q.9 $m_1 = 20$kg, $m_2 = 30$kg. m_2 is on smooth surface. Surface between m_1 and m_2 has $\mu_s = 0.5$ and $\mu_k = 0.3$. Find the acceleration of m_1 and m_2 for the following cases
(a) (i) F = 160 N, (ii) F = 175 N ; (b) F = 160 N



(a) (b)

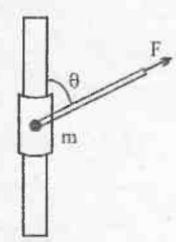
Q.10 A system of masses is shown in the figure with masses & co-efficients of friction indicated. Calculate :
(i) the maximum value of F for which there is no slipping anywhere.
(ii) the minimum value of F for which B slides on C.
(iii) the minimum value of F for which A slips on B.



Q.11 A car begins to move at time t = 0 and then accelerates along a straight track with a speed given by
$V(t) = 2t^2\ ms^{-1}$ for $0 \le t \le 2$
After the end of acceleration, the car continues to move at a constant speed. A small block initially at rest on the floor of the car begins to slip at t = 1sec. and stops slipping at t = 3 sec. Find the coefficient of static and kinetic friction between the block and the floor.

Q.12 A smooth right circular cone of semi vertical angle $\alpha = \tan^{-1}(5/12)$ is at rest on a horizontal plane. A rubber ring of mass 2.5kg which requires a force of 15N for an extension of 10cm is placed on the cone. Find the increase in the radius of the ring in equilibrium.

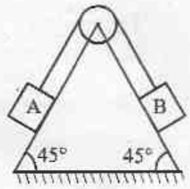
Q.13 The collar of mass m slides up the vertical shaft under the action of a force F of constant magnitude but variable direction of $\theta = kt$ where k is a constant and if the collar starts from rest with $\theta = 0$, determine the magnitude F of the force that will result in the collar coming to rest as θ reaches $\pi/2$. The coefficient of kinetic friction between the collar and the shaft is μ_k.



EXERCISE–III

Q.1 A block of mass 0.1kg is held against a wall by applying a horizontal force of 5N on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is
(A) 2.5N (B) 0.98N (C) 4.9N (D) 0.49N [JEE 1997]

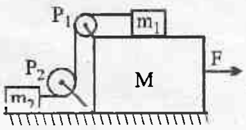
Q.2 Block A of mass m and block B of mass 2m are placed on a fixed triangular wedge by means of a massless inextensible string and a frictionless pulley as shown in the figure. The wedge is inclined at 45° to the horizontal on both sides. The coefficient of friction between block A and the wedge is 2/3 and that between block B and the wedge is 1/3. If the system of A and B is released from rest, find (i) the acceleration of A, (ii) tension in the string, (iii) the magnitude and the direction of friction acting on A. [JEE 1997]



Q.3 A spring of force constant k is cut into two pieces such that one piece such that one piece is double the length of the other. Then the long piece will have a force constant of

(A) (2/3) k (B) (3/2) k (C) 3k (D) 6k [JEE 1999]

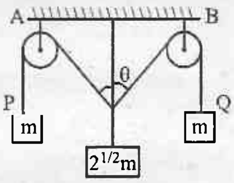
Q.4 In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively. The co-efficient of friction between M and ground is zero. The co-efficient of friction between m_1 and M and that between m_2 and ground is 0.3. The pulleys and the string are massless. The string is perfectly horizontal between P_1 and m_1 and also between P_2 and m_2. The string is perfectly vertical between P_1 and P_2. An external horizontal force F is applied to the mass M. Take $g = 10\ m/s^2$.



(a) Draw a free-body diagram for mass M, clearly showing all the forces.

(b) Let the magnitude of the force of friction between m_1 and M be f_1 and that between m_2 and ground be f_2. For a particular F it is found that $f_1 = 2f_2$. Find f_1 and f_2. Write down equations of motion of all the masses. Find F, tension in the string and accelerations of the masses. [JEE 2000]

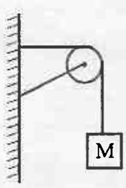
Q.5 The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be [JEE (Scr) 2001]



(A) 0° (B) 30°

(C) 45° (D) 60°

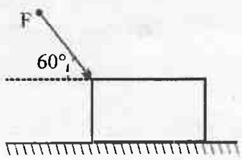
Q.6 A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given [JEE (Scr) 2001]



(A) $\sqrt{2}$ Mg (B) $\sqrt{2}$ mg

(C) $\sqrt{(M+m)^2+m^2}\ g$ (D) $\sqrt{(M+m)^2+M^2}\ g$

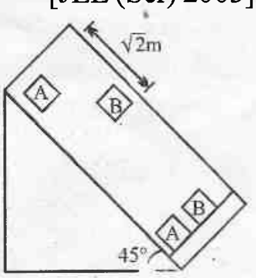
Q.7 A block of mass $\sqrt{3}$ kg is placed on a rough horizontal surface whose coefficient of friction is $1/2\sqrt{3}$ minimum value of force F (shown in figure) for which the block starts to slide on the surface. (g=10m/s²)



(A) 20 N (B) $20\sqrt{3}$ N

(C) $10\sqrt{3}$ N (D) None of these [JEE (Scr) 2003]

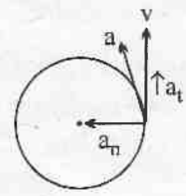
Q.8 Two blocks A and B of equal masses are released from an inclined plane of inclination 45° at t = 0. Both the blocks are initially at rest. The coefficient of kinetic friction between the block A and the inclined plane is 0.2 while it is 0.3 for block B. Initially, the block A is $\sqrt{2}$ m behind the block B. When and where their front faces will come in a line. [Take g = 10 m/s²]. [JEE 2004]



1. A body moving with constant speed in a circular path is continuously accelerated towards the centre of rotation. The magnitude of this normal acceleration is given by

$$a_n = \frac{v^2}{r} = \omega^2 r$$

where v is the constant speed ($v = \omega r$) and r is the radius of the circular path



Tangential area : $a_t = \frac{dv}{dt}$, $a = \sqrt{at^2 + a_n^2}$

2. **Radius of curvature :** $r = \frac{v^2}{a_n}$

3. According to Newton's second law, a body moving in a circular path with constant speed must be acted upon by an unbalanced force which is always directed towards the centre. This necessary unbalanced force is called the centripetal force.

$$F = \frac{mv^2}{r} = m\omega^2 r$$

4. Centrifugal force is a pseudo force which is observed an observer in rotating frame.

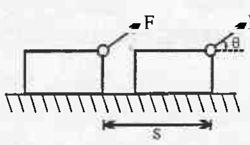
$$\vec{F}_{cf} = m\omega^2_{frame}\,\vec{r}$$

Work (W) :

The **work W** done by a constant force F when its point of application undergoes a displacement s is defined as

$$W = F.s = Fs\cos\theta$$

where θ is the angle between F and s. Work is a scalar quantity and its SI units is N-m or joule (J).



Note: Only the component ($F\cos\theta$) of the force F which is along the displacement contributes to the work done.

If $F = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$ and $s = \Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}$

then $W = \vec{F}\cdot\vec{s} = F_x\Delta x + F_y\Delta y + F_z\Delta z$

5. **Work done by a Variable Force :** When the magnitude and direction of a force varies with position, The work done by such a force for an infinitesimal displacement ds is given by

$$dW = \vec{F}\cdot d\vec{s}$$

In terms of rectangular components,

$$W_{AB} = \int_{X_A}^{X_B} F_x dx + \int_{Y_A}^{Y_B} F_y dy + \int_{Z_A}^{Z_B} F_z dz$$

6. **Work Done by a Spring Force :** The work done by the spring force for a displacement from x_i to x_f is given by

$$W_s = -\frac{1}{2}k\left(x_f^2 - x_i^2\right)$$

7. **Work Energy theorem :**
Work done on a body can produce a change in its kinetic energy. Work is required to produce motion and it is also required to destroy motion.

$$W = \Delta K = K_f - K_i$$

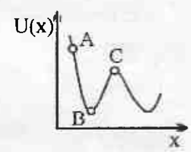
8. **Conservative Force :** The force which does work in complete independence of the path followed the body is called a conservative force. The gravitational force, spring force and electrostatic force are the examples of conservative forces.

9. **Non-Conservative Force :** The work done by a non-conservative force not only depends on the initial and final positions but also on the path followed. The common examples of such forces are : frictional force and drag force of fluids.

10. **Potential Energy :** The potential energy is defined only for conservative forces.

$$U_B - U_A = -\int_A^B F_c . ds$$

11. Conservative force : $F_c = -\frac{dU}{dx}$



At equilibrium, $\frac{dU}{dx} = 0$

The point B is the position of stable equilibrium, because $\frac{d^2U}{dx^2} > 0$

The point C is the position odf unstable equilibrium, because $\frac{d^2U}{dx^2} < 0$

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (P, Q, R, S)

IIT-JEE SCREENING 2007

QUESTION BANK ON

PARTICLE DYNAMICS

Time Limit : 3 Sitting Each of 60 minutes. duration approx.

QUESTION ON PARTICLE DYNAMICS

There are 81 questions in this question bank.

Q.1 A small block of mass m is projected horizontally with speed u where friction coefficient between block and plane is given by $\mu = cx$, where x is displacement of the block on plane. Find maximum distance covered by the block

(A) $\frac{u}{\sqrt{cg}}$ (B) $\frac{u}{\sqrt{2cg}}$ (C) $\frac{2u}{\sqrt{cg}}$ (D) $\frac{u}{2\sqrt{cg}}$

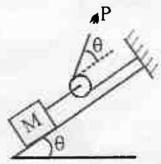
Q.2 A body is placed on a rough inclined plane of inclination θ. As the angle θ is increased from 0° to 90° the contact force between the block and the plane

(A) remains constant
(B) first remains constant than decreases
(C) first decreases then increases
(D) first increases then decreases

Q.3 A block is projected upwards on an inclined plane of inclination 37° along the line of greatest slope of $\mu = 0.5$ with velocity of 5 m/s. The block 1st stops at a distance of __________ from starting point

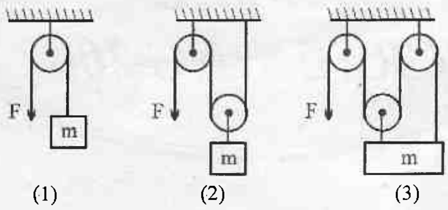
(A) 1.25 m (B) 2.5 m (C) 10 m (D) 12.5 m

Q.4 What should be the minimum force P to be applied to the string so that block of mass m just begins to move up the frictionless plane.



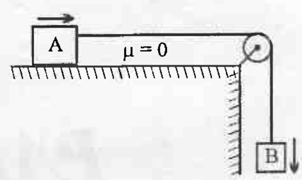
(A) $Mg \tan \theta/2$ (B) $Mg \cot \theta/2$ (C) $\frac{Mg\cos\theta}{1+\sin\theta}$ (D) None

Q.5 Equal force F (> mg) is applied to string in all the 3 cases. Starting from rest, the point of application of force moves a distance of 2 m down in all cases. In which case the block has maximum kinetic energy?



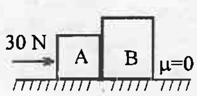
(A) 1 (B) 2 (C) 3 (D) equal in all 3 cases

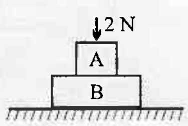
Q.6 Both the blocks shown here are of mass m and are moving with constant velocity in direction shown in a resistive medium which exerts equal constant force on both blocks in direction opposite to the velocity. The tension in the string connecting both of them will be : (Neglect friction)

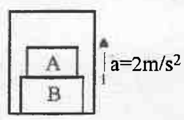


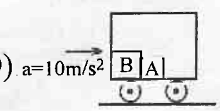
(A) mg
(B) mg/2
(C) mg/3
(D) mg/4

Q.7 In which of the following cases is the contact force between A and B maximum ($m_A = m_B = 1$ kg)

(A) 

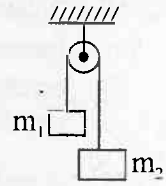
(B) 

(C) 

(D) 

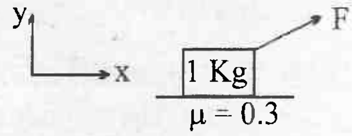
Q.8 A student calculates the acceleration of m_1 in figure shown as

$a_1 = \dfrac{(m_1 - m_2)g}{m_1 + m_2}$. Which assumption is not required to do this calculation.



(A) pulley is frictionless (B) string is massless
(C) pulley is massless (D) string is inextensible

Q.9 A force $\vec{F} = \hat{i} + 4\hat{j}$ acts on block shown. The force of friction acting on the block is :



(A) $-\hat{i}$ (B) $-1.8\hat{i}$
(C) $-2.4\hat{i}$ (D) $-3\hat{i}$

Q.10 A body of mass m accelerates uniformly from rest to a speed v_0 in time t_0. The work done on the body till any time t is

(A) $\frac{1}{2}mv_0^2\left(\frac{t^2}{t_0^2}\right)$ (B) $\frac{1}{2}mv_0^2\left(\frac{t_0}{t}\right)$ (C) $mv_0^2\left(\frac{t}{t_0}\right)$ (D) $mv_0^2\left(\frac{t}{t_0}\right)^3$

Q.11 A man who is running has half the kinetic energy of the boy of half his mass. The man speeds up by 1 m/s and then has the same kinetic energy as the boy. The original speed of the man was

(A) $\sqrt{2}$ m/s (B) $(\sqrt{2} - 1)$ m/s (C) 2 m/s (D) $(\sqrt{2} + 1)$ m/s

Q.12 A particle originally at rest at the highest point of a smooth vertical circle is slightly displaced. It will leave the circle at a vertical distance h below the highest point, such that

(A) h = R (B) h = R/3 (C) h = R/2 (D) h = 2R

Q.13 $F = 2x^2 - 3x - 2$. Choose correct option

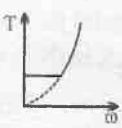
(A) x = – 1/2 is position of stable equilibrium (B) x = 2 is position of stable equilibrium
(C) x = – 1/2 is position of unstable equilibrium (D) x = 2 is position of neutral equilibrium

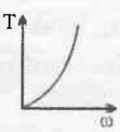
Q.14 A block of mass m is hung vertically from an elastic thread of force constant mg/a. Initially the thread was at its natural length and the block is allowed to fall freely. The kinetic energy of the block when it passes through the equilibrium position will be :

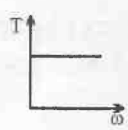
(A) mga (B) mga/2 (C) zero (D) 2mga

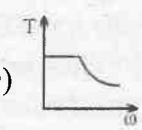
Q.15 In a conical pendulum, the bob is rotated with different angular velocities and tension in the string is calculated for different values of ω. Which of them is correct graph between T & ω.



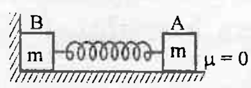
(A) 

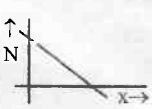
(B) 

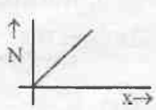
(C) 

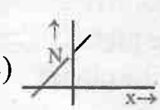
(D) 

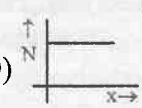
Q.16 The block A is pushed towards the wall by a distance and released. The normal reaction by vertical wall on the block B v/s compression in spring is given by :



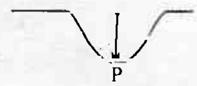
(A) 

(B) 

(C) 

(D) 

Q.17 A car travelling on a smooth road passes through a curved portion of the road in form of an arc of circle of radius 10 m. If the mass of car is 500 kg, the reaction on car at lowest point P where its speed is 20 m/s is

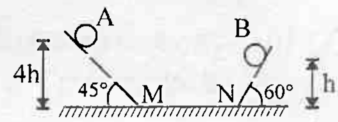


(A) 35 kN (B) 30 kN (C) 25 kN (D) 20 kN

Q.18 A particle with constant total energy E moves in one dimension in a region where the potential energy is U(x). The speed of the particle is zero where

(A) $U(x) = E$ (B) $U(x) = 0$ (C) $\frac{dU(x)}{dx} = 0$ (D) $\frac{d^2U(x)}{dx^2} = 0$

Q.19 Two identical balls A and B are released from the positions shown in figure. They collide elastically on horizontal portion MN. All surfaces are smooth. The ratio of heights attained by A and B after collision will be(Neglect energy loss at M & N)



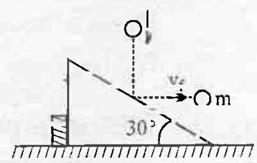
(A) 1 : 4 (B) 2 : 1
(C) 4 : 13 (D) 2 : 5

Q.20 A particle moving with kinetic energy = 3 joule makes an elastic head on collision with a stationary particle which has twice its mass during the impact.
(A) The minimum kinetic energy of the system is 1 joule.
(B) The maximum elastic potential energy of the system is 2 joule.
(C) Momentum and total kinetic energy of the system are conserved at every instant.
(D) The ratio of kinetic energy to potential energy of the system first decreases and then increases.

Q.21 A ball of mass m collides elastically with an identical ball at rest with some impact parameter.
(A) 100 % energy transfer can never take place
(B) 100 % energy transfer may take place
(C) angle of divergence between the two balls must be 90°
(D) angle of divergence between the two balls depend on impact parameter

Q.22 A ball strikes a smooth horizontal ground at an angle of 45° with the vertical. What **cannot** be the possible angle of its velocity with the vertical after the collision. (Assume $e \le 1$).
(A) 45° (B) 30° (C) 53° (D) 60°

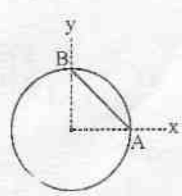
Q.23 As shown in the figure a body of mass m moving vertically with speed 3 m/s hits a smooth fixed inclined plane and rebounds with a velocity v_f in the horizontal direction. If ∠ of inclined is 30°, the velocity v_f will be



(A) 3 m/s (B) $\sqrt{3}$ m/s
(C) $1/\sqrt{3}$ m/s (D) this is not possible

Q.24 Two balls A and B having masses 1 kg and 2 kg, moving with speeds 21 m/s and 4 m/s respectively in opposite direction, collide head on. After collision A moves with a speed of 1 m/s in the same direction, then correct statements is :
(A) The velocity of B after collision is 6 m/s opposite to its direction of motion before collision.
(B) The coefficient of restitution is 0.2.
(C) The loss of kinetic energy due to collision is 200 J.
(D) The impulse of the force between the two balls is 40 Ns.

Q.25 An object comprises of a uniform ring of radius R and its uniform chord AB (not necessarily made of the same material) as shown. Which of the following can not be the centre of mass of the object



(A) (R/3, R/3) (B) (R/3, R/2)
(C) (R/4, R/4) (D) $(R/\sqrt{2}, R/\sqrt{2})$

Q.26 An ice block is melting at a constant rate $\left|\frac{dm}{dt}\right| = \mu$. Its initial mass is m_0 and it is moving with velocity on a frictionless horizontal surface. The distance travelled by it till it melts completely is :

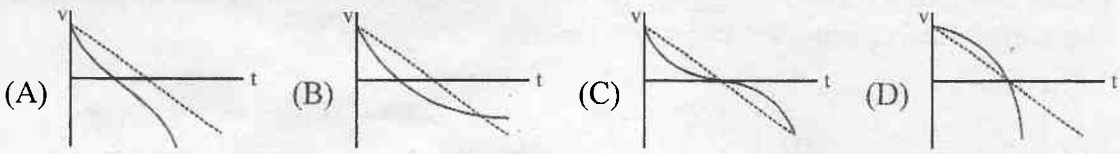
(A) $\frac{2m_0v}{\mu}$ (B) $\frac{m_0v}{\mu}$ (C) $\frac{m_0v}{2\mu}$ (D) can't be said

Q.27 A ball A collides elastically with another identical ball B initially at rest A is moving with velocity of 10m/s at an angle of 60° from the line joining their centres. Select correct alternative :

(A) velocity of ball A after collision is 5 m/s
(B) velocity of ball B after collision is $5\sqrt{3}$ m/s
(C) velocity of ball A after collision is 7.5 m/s
(D) velocity of ball B after collision is 5 m/s.

Q.28 Force acting on a body of mass 1 kg is related to its position x as $F = x^3 - 3x$ N. It is at rest at $x = 1$. Its velocity at $x = 3$ can be :
(A) 4 m/s (B) 3 m/s (C) 2 m/s (D) 5 m/s

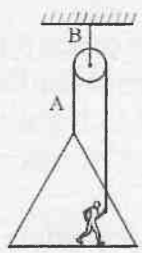
Q.29 Which graph shows best the velocity-time graph for an object launched vertically into the air when air resistance is given by $|D| = bv$? The dashed line shows the velocity graph if there were no air resistance.



Q.30 A 1.0 kg block of wood sits on top of an identical block of wood, which sits on top of a flat level table made of plastic. The coefficient of static friction between the wood surfaces is μ_1, and the coefficient of static friction between the wood and plastic is μ_2.
A horizontal force F is applied to the top block only, and this force is increased until the top block starts to move. The bottom block will move with the top block if and only if

(A) $\mu_1 < \frac{1}{2}\mu_2$ (B) $\frac{1}{2}\mu_2 < \mu_1 < \mu_2$ (C) $\mu_2 < \mu_1$ (D) $2\mu_2 < \mu_1$

Q.31 To paint the side of a building, painter normally hoists himself up by pulling on the rope A as in figure. The painter and platform together weigh 200N. The rope B can withstand 300N. Then

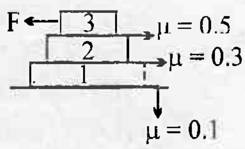


(A) The maximum acceleration that painter can have upwards is $5 m/s^2$.
(B) To hoist himself up, rope B must withstand minimum 400N force.
(C) Rope A will have a tension of 100 N when the painter is at rest.
(D) The painter must exert a force of 200N on the rope A to go downwards slowly.

Q.32 A block of mass 2 kg slides down an incline plane of inclination 30°. The coefficient of friction between block and plane is 0.5. The contact force between block and plank is :

(A) 20 Nt (B) $10\sqrt{3}$ Nt (C) $5\sqrt{7}$ Nt (D) $5\sqrt{15}$ Nt

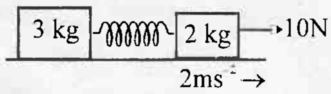
Q.33 If force F is increasing with time and at t = 0 , F = 0 where will slipping first start?



(A) between 3 kg and 2 kg
(B) between 2 kg and 1 kg
(C) between 1 kg and ground
(D) both (A) and (B)

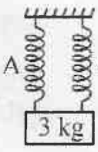
Q.34 A rope of mass 5 kg is moving vertically in vertical position with an upwards force of 100 N acting at the upper end and a downwards force of 70 N acting at the lower end. The tension at midpoint of the rope is
(A) 100 N (B) 85 N (C) 75 N (D) 105 N

Q.35 Find the acceleration of 3 kg mass when acceleration of 2 kg mass is $2\ ms^{-2}$ as shown in figure.



(A) $3\ ms^{-2}$ (B) $2\ ms^{-2}$
(C) $0.5\ ms^{-2}$ (D) zero

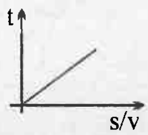
Q.36 Block of 1 kg is initially in equilibrium and is hanging by two identical springs A and B as shown in figures. If spring A is cut from lower point at t=0 then, find acceleration of block in ms^{-2} at t = 0.

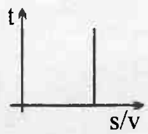


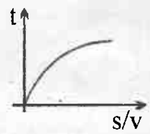
(A) 5 (B) 10 (C) 15 (D) 0

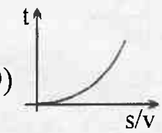
Q.37 Assume the aerodynamic drag force on a car is proportional to its speed. If the power output from the engine is doubled, then the maximum speed of the car.
(A) is unchanged (B) increases by a factor of $\sqrt{2}$
(C) is also doubled (D) increases by a factor of four.

Q.38 A body is moved from rest along a straight line by a machine delivering constant power. The ratio of displacement and velocity (s/v) varies with time t as :

(A) 

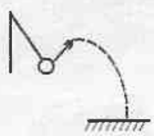
(B) 

(C) 

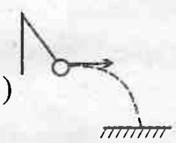
(D) 

Q.39 A pendulum bob is swinging in a vertical plane such that its angular amplitude is less than 90^0. At its highest point, the string is cut. Which trajectory is possible for the bob afterwards.

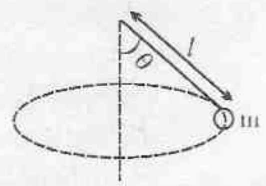
(A) 

(B) 

(C) 

(D) 

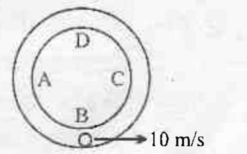
Q.40 A conical pendulum is moving in a circle with angular velocity ω as shown. If tension in the string is T, which of following equations are correct ?



(A) $T = m\omega^2 l$ (B) $T \sin\theta = m\omega^2 l$
(C) $T = mg \cos\theta$ (D) $T = m\omega^2 l \sin\theta$

Q.41 A particle is released from rest at origin. It moves under influence of potential field $U = x^2 - 3x$, kinetic energy at x = 2 is
(A) 2J (B) 1 J (C) 1.5 J (D) 0 J

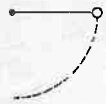
Q.42 A ball whose size is slightly smaller than width of the tube of radius 2.5 m is projected from bottommost point of a smooth tube fixed in a vertical plane with velocity of 10 m/s. If N_1 and N_2 are the normal reactions exerted by inner side and outer side of the tube on the ball
(A) $N_1 > 0$ for motion in ABC, $N_2 > 0$ for motion in CDA
(B) $N_1 > 0$ for motion in CDA, $N_2 > 0$ for motion in ABC
(C) $N_2 > 0$ for motion in ABC & part of CDA
(D) N_1 is always zero.

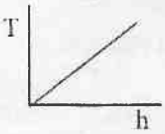


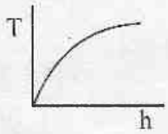
Q.43 A man is standing on a rough ($\mu = 0.5$) horizontal disc rotating with constant angular velocity of 5 rad/sec. At what distance from centre should he stand so that he does not slip on the disc?
(A) $R \le 0.2$m (B) $R > 0.2$ m (C) $R > 0.5$ m (D) $R > 0.3$ m

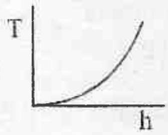
Q.44 A road is banked at an angle of 30° to the horizontal for negotiating a curve of radius $10\sqrt{3}$ m. At what velocity will a car experience no friction while negotiating the curve?
(A) 54 km/hr (B) 72 km/hr (C) 36 km/hr (D) 18 km/hr

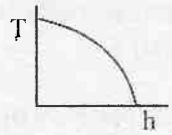
Q.45 A bob attached to a string is held horizontal and released. The tension and vertical distance from point of suspension can be represented by.



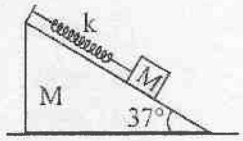
(A) 

(B) 

(C) 

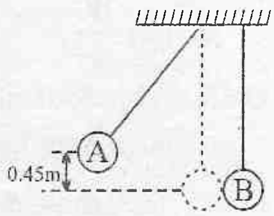
(D) 

Q.46 The system of the wedge and the block connected by a massless spring as shown in the figure is released with the spring in its natural length. Friction is absent. maximum elongation in the spring will be



(A) $\frac{3Mg}{5k}$ (B) $\frac{6Mg}{5k}$ (C) $\frac{4Mg}{5k}$ (D) $\frac{8Mg}{5k}$

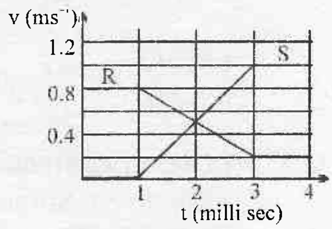
Q.47 Two massless string of length 5 m hang from the ceiling very near to each other as shown in the figure. Two balls A and B of masses 0.25 kg and 0.5 kg are attached to the string. The ball A is released from rest at a height 0.45 m as shown in the figure. The collision between two balls is completely elastic. Immediately after the collision, the kinetic energy of ball B is 1 J. The velocity of ball A just after the collision is



(A) 5 ms^{-1} to the right (B) 5 ms^{-1} to the left
(C) 1 ms^{-1} to the right (D) 1 ms^{-1} to the left

Q.48 Consider following statements
[1] CM of a uniform semicircular disc of radius R = $2R/\pi$ from the centre
[2] CM of a uniform semicircular ring of radius R = $4R/3\pi$ from the centre
[3] CM of a solid hemisphere of radius R = $4R/3\pi$ from the centre
[4] CM of a hemisphere shell of radius R = R/2 from the centre
Which statements are correct?
(A) 1, 2, 4 (B) 1, 3, 4 (C) 4 only (D) 1, 2 only

Q.49 The diagram to the right shows the velocity-time graph for two masses R and S that collided elastically. Which of the following statements is true?



(I) R and S moved in the same direction after the collision.
(II) Kinetic energy of the system (R & S) is minimum at t = 2 milli sec.
(III) The mass of R was greater than mass of S.
(A) I only (B) II only (C) I and II only (D) I, II and III

Q.50 A smooth sphere is moving on a horizontal surface with a velocity vector $(2\hat{i} + 2\hat{j})$ m/s immediately before it hit a vertical wall. The wall is parallel to vector $\hat{j}$ and coefficient of restitution between the sphere and the wall is $e = 1/2$. The velocity of the sphere after it hits the wall is
(A) $\hat{i} - \hat{j}$ (B) $-\hat{i} + 2\hat{j}$ (C) $-\hat{i} - \hat{j}$ (D) $2\hat{i} - \hat{j}$

Q.51 A man of mass M stands at one end of a plank of length L which lies at rest on a frictionless surface. The man walks to other end of the plank. If the mass of the plank is $\frac{M}{3}$, then the distance that the man moves relative to ground is :

(A) $\frac{3L}{4}$ (B) $\frac{L}{4}$ (C) $\frac{4L}{5}$ (D) $\frac{L}{3}$

Q.52 Two balls A and B having masses 1 kg and 2 kg, moving with speeds 21 m/s and 4 m/s respectively in opposite direction, collide head on. After collision A moves with a speed of 1 m/s in the same direction, then the coefficient of restitution is

(A) 0.1 (B) 0.2 (C) 0.4 (D) None

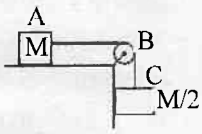
Q.53 Two particles of equal mass have velocities $2\hat{i}\ ms^{-1}$ and $2\hat{j}\ ms^{-1}$. First particle has an acceleration $(\hat{i}+\hat{j})\,ms^{-2}$ while the acceleration of the second particle is zero. The centre of mass of the two particles moves in

(A) circle (B) parabola (C) ellipse (D) straight line

Q.54 A particle of mass 3m is projected from the ground at some angle with horizontal. The horizontal range is R. At the highest point of its path it breaks into two pieces m and 2m. The smaller mass comes to rest and larger mass finally falls at a distance x from the point of projection where x is equal to

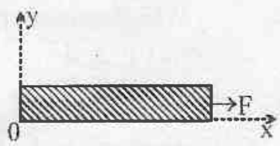
(A) $\frac{3R}{4}$ (B) $\frac{3R}{2}$ (C) $\frac{5R}{4}$ (D) 3R

Q.55 A block of mass M on a horizontal smooth surface is pulled by a load of mass $M/2$ by means of a rope AB and string BC as shown in the figure. The length & mass of the rope AB are L and $M/2$ respectively. As the block is pulled from AB = L to AB = 0 its acceleration changes from



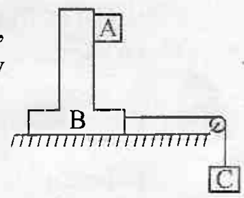
(A) $\frac{3g}{4}$ to g (B) $\frac{g}{4}$ to $\frac{g}{2}$ (C) $\frac{g}{4}$ to g (D) $\frac{3g}{2}$ to 2g

Q.56 A uniform rod of length L and mass M has been placed on a rough horizontal surface. The horizontal force F applied on the rod is such that the rod is just in the state of rest. If the coefficient of friction varies according to the relation $\mu = Kx$ where K is a +ve constant. Then the tension at mid point of rod is



(A) F/2 (B) F/4
(C) F/8 (D) None

Q.57 In the arrangement shown in the figure, mass of the block B and A is 2m and m respectively. Surface between B and floor is smooth. The block B is connected to the block C by means of a string pulley system. If the whole system is released, then find the minimum value of mass of block C so that block A remains stationary w.r.t. B. Coefficient of friction between A and B is μ :

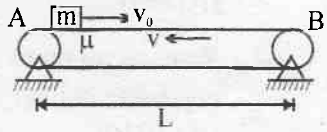


(A) $\frac{m}{\mu}$ (B) $\frac{2m+1}{\mu+1}$ (C) $\frac{3m}{\mu-1}$ (D) $\frac{6m}{\mu+1}$

Q.58 A particle of mass m, initially at rest, is acted on by a force $F = F_0 \left\{1 - \left(\frac{2t - T}{T}\right)^2\right\}$ during the interval $0 \le t \le T$. The velocity of the particle at the end of the interval is :

(A) $\frac{5F_0T}{6m}$ (B) $\frac{4F_0T}{3m}$ (C) $\frac{2F_0T}{3m}$ (D) $\frac{3F_0T}{2m}$

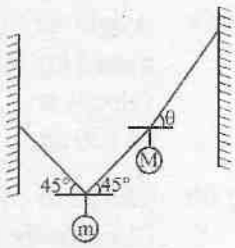
Q.59 With what minimum velocity should block be projected from left end A towards end B such that it reaches the other end B of conveyer belt moving with constant velocity v. Friction coefficient between block and belt is μ.



(A) $\sqrt{\mu gL}$ (B) $\sqrt{2\mu gL}$

(C) $\sqrt{3\mu gL}$ (D) $2\sqrt{\mu gL}$

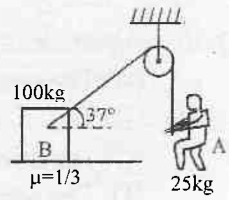
Q.60 Two masses m and M are attached to the strings as shown in the figure. If the system is in equilibrium, then



(A) $\tan\theta = 1 + \frac{2M}{m}$ (B) $\tan\theta = 1 + \frac{2m}{M}$

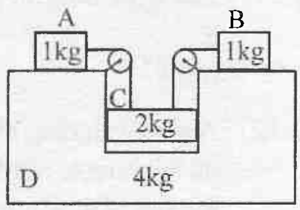
(C) $\cot\theta = 1 + \frac{2M}{m}$ (D) $\cot\theta = 1 + \frac{2m}{M}$

Q.61 Block B of mass 100 kg rests on a rough surface of friction coefficient μ = 1/3. A rope is tied to block B as shown in figure. The maximum acceleration with which boy A of 25 kg can climbs on rope without making block move is :



(A) $\frac{4g}{3}$ (B) $\frac{g}{3}$ (C) $\frac{g}{2}$ (D) $\frac{3g}{4}$

Q.62 In the system shown in the figure there is no friction anywhere. The block C goes down by a distance $x_0 = 10$ cm with respect to wedge D when system is released from rest. The velocity of A with respect to B will be ($g = 10\ m/s^2$) :



(A) zero (B) 1 m/s

(C) 2 m/s (D) None of these

Q.63 A car moves along a circular track of radius R banked at an angle of 30° to the horizontal. The coefficient of static friction between the wheels and the track is μ. The maximum speed with which the car can move without skidding out is

(A) $\left[2gR(1+\mu)/\sqrt{3}\right]^{1/2}$ (B) $\left[gR(1-\mu)/(\mu+\sqrt{3})\right]^{1/2}$

(C) $\left[gR(1+\mu\sqrt{3})/(\mu+\sqrt{3})\right]^{1/2}$ (D) None

Q.64 Potential energy of a particle is related to x coordinate by equation $x^2 - 2x$. Particle will be in stable equilibrium at

(A) x = 0.5 (B) x = 1 (C) x = 2 (D) x = 4

Q.65 A particle of mass m is tied to one end of a string of length l. The particle is held horizontal with the string taut. It is then projected upward with a velocity u. The tension in the string is $\frac{mg}{2}$ when it is inclined at an angle $30°$ to the horizontal. The value of u is

(A) $\sqrt{lg}$ (B) $\sqrt{2lg}$ (C) $\sqrt{\frac{lg}{2}}$ (D) $2\sqrt{lg}$

Q.66 A force $\vec{F} = k[y\hat{i} + x\hat{j}]$ where k is a positive constant acts on a particle moving in x-y plane starting from the point (3,5), the particle is taken along a straight line to (5, 7). The work done by the force is :

(A) zero (B) 35 K (C) 20 K (D) 15 K

Q.67 Water is pumped from a depth of 10 m and delivered through a pipe of cross section $10^{-2}m^2$. If it is needed to deliver a volume of 10^{-1} m^3 per second the power required will be:

(A) 10 kW (B) 9.8 kW (C) 15 kW (D) 4.9 kW

Q.68 A light spring of length 20 cm and force constant 2 kg/cm is placed vertically on a table. A small block of mass 1 kg. falls on it. The length h from the surface of the table at which the ball will have the maximum velocity is

(A) 20 cm (B) 15 cm (C) 10 cm (D) 5 cm

Q.69 The ratio of period of oscillation of the conical pendulum to that of the simple pendulum is : (Assume the strings are of the same length in the two cases and θ is the angle made by the string with the verticla in case of conical pendulum)

(A) $\cos\theta$ (B) $\sqrt{\cos\theta}$ (C) 1 (D) none of these

Q.70 A particle is moving in a circle :

(A) The resultant force on the particle must be towards the centre.
(B) The cross product of the tangential acceleration and the angular velocity will be zero.
(C) The direction of the angular acceleration and the angular velocity must be the same.
(D) The resultant force may be towards the centre.

Q.71 The work done in joules in increasing the extension of a spring of stiffness 10 N/cm from 4 cm to 6 cm is :

(A) 1 (B) 10 (C) 50 (D) 100

Q.72 A man weighing 80 kg is standing at the centre of a flat boat and he is 20 m from the shore. He walks 8 m on the boat towards the shore and then halts. The boat weight 200 kg. How far is he from the shore at the end of this time ?

(A) 11.2 m (B) 13.8 m (C) 14.3 m (D) 15.4 m

Q.73 From a circle of radius a, an isosceles right angled triangle with the hypotenuse as the diameter of the circle is removed. The distance of the centre of gravity of the remaining position from the centre of the circle is

(A) $3(\pi - 1)a$ (B) $\frac{(\pi - 1)a}{6}$ (C) $\frac{a}{3(\pi-1)}$ (D) $\frac{a}{3(\pi+1)}$

Q.74 A sphere strikes a wall and rebounds with coefficient of restitution 1/3. If it rebounds with a velocity of 0.1 m/sec at an angle of 60° to the normal to the wall, the loss of kinetic energy is

(A) 50% (B) $33\frac{1}{3}$% (C) 40% (D) $66\frac{2}{3}$%

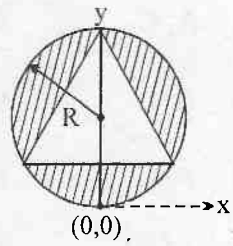
Q.75 A truck moving on horizontal road towards east with velocity 20 ms^{-1} collides elastically with a light ball moving with velocity 25 ms^{-1} along west. The velocity of the ball just after collision

(A) 65 ms^{-1} towards east
(B) 25 ms^{-1} towards west
(C) 65 ms^{-1} towards west
(D) 20 ms^{-1} towards east

Q.76 A spaceship of speed v_0 travelling along + y axis suddenly shots out one fourth of its part with speed $2v_0$ along + x-axis. xy axes are fixed with respect to ground. The velocity of the remaining part is

(A) $\frac{2}{3}v_0$
(B) $\frac{\sqrt{20}}{3}v_0$
(C) $\frac{\sqrt{5}}{3}v_0$
(D) $\frac{\sqrt{13}}{3}v_0$

Q.77 From a uniform disc of radius R, an equilateral triangle of side $\sqrt{3}$ R is cut as shown. The new position of centre of mass is :



(A) (0, 0)
(B) (0, R)
(C) $(0, \frac{\sqrt{3}R}{2})$
(D) none of these

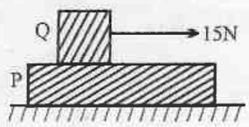
Q.78 In an inelastic collision,

(A) the velocity of both the particles may be same after the collision
(B) kinetic energy is not conserved
(C) linear momentum of the system is conserved.
(D) velocity of separation will be less than velocity of approach.

Q.79 A man of mass 40 kg is standing on a trolley A of mass 140 kg . He pushes another trolley B of same material of mass 60 kg, so that they are set in motion . Then :

(A) speed of trolley A is 3 times that of trolley B immediately after the interaction.
(B) speed of trolley B is 3 times that of trolley A immediately after the interaction.
(C) distance travelled by trolley B is 3 times that of trolley A before they stop.
(D) distance travelled by trolley B is 9 times that of trolley A before they stop.

Q.80 A long plank P of the mass 5 kg is placed on a smooth floor. On P is placed a block Q of mass 2 kg. The coefficient of friction between P and Q is 0.5. If a horizontal force 15N is applied to Q, as shown, and you may take g as 10N/kg.



(A) The reaction force on Q due to P is 10N
(B) The acceleration of Q relative to P is 2.5 m/s^2
(C) The acceleration of P relative to the Floor is 2.0 m/s^2
(D) The acceleration of centre of mass of P + Q system relative to the floor is (15/7)m/s^2

Q.81 If the linear density of a rod of length 3 m varies as $\lambda = 2 + x$, then the position of centre of gravity of the rod is :

(A) 7/3 m
(B) 12/7 m
(C) 10/7 m
(D) 9/7 m

ANSWER KEY

Q.1 A	Q.2 B	Q.3 A	Q.4 A	Q.5 C
Q.6 B	Q.7 A	Q.8 C	Q.9 A	Q.10 A
Q.11 D	Q.12 B	Q.13 A	Q.14 B	Q.15 A
Q.16 B	Q.17 C	Q.18 A	Q.19 C	Q.20 A, B, D
Q.21 A, C	Q.22 B	Q.23 B	Q.24 A, B, C	Q.25 B, D
Q.26 B	Q.27 D	Q.28 A	Q.29 B	Q.30 D
Q.31 A, C	Q.32 D	Q.33 C	Q.34 B	Q.35 B
Q.36 A	Q.37 B	Q.38 A	Q.39 C	Q.40 A
Q.41 A	Q.42 C	Q.43 A	Q.44 C	Q.45 A
Q.46 B	Q.47 D	Q.48 C	Q.49 D	Q.50 B
Q.51 B	Q.52 B	Q.53 D	Q.54 C	Q.55 B
Q.56 B	Q.57 C	Q.58 C	Q.59 B	Q.60 A
Q.61 B	Q.62 C	Q.63 D	Q.64 B	Q.65 B
Q.66 C	Q.67 C	Q.68 B	Q.69 B	Q.70 D
Q.71 A	Q.72 C	Q.73 C	Q.74 D	Q.75 A
Q.76 B	Q.77 B	Q.78 A,B,C,D	Q.79 B, D	
Q.80 C, D	Q.81 B			

BANSAL CLASSES

TARGET IIT JEE 2007

PHYSICS

XII & XIII

REVISION PRACTICE PROBLEMS FOR JEE-2007

(With Solutions)

- ❑ 2 bonus question of Mathematics

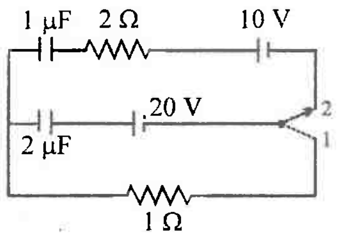
ALL THE BEST FOR JEE -2007

2 Bonus question of Mathematics

Q.1 If $L = \lim_{x \to 0} \left(\frac{1}{ln(1+x)} - \frac{1}{ln(x+\sqrt{1+x^2})} \right)$ then find the value of $\frac{L+153}{L}$.

Q.2 Two universities A and B write questions and their corresponding solutions for a high school mathematics tournament. University A writes 10 questions every hour but makes a mistake in their solutions 10% of the time. The university B writes 20 questions every hour and makes a mistake 20% of the time. Each university works for 10 hours and then sends all problems to a Miss 'C' for checking. However only 75% of the problems which she thinks are wrong are actually incorrect. Further she thinks that 20% of the questions from the university A have incorrect solutions, and that 10% of the questions from the university B have incorrect solutions.
If the probability that a problem definitely written and solved correctly, randomly chosen by her, was thought of as having incorrectly solved, is $\frac{p}{q}$ where p and q coprimes, then find the value of $(p + q)$.

PHYSICS QUESTION



Q.1 In the circuit shown, the switch S is in position-1 since a long time. At a certain moment t = 0, it is shifted to position-2. The 1 μF capacitor is initially uncharged.

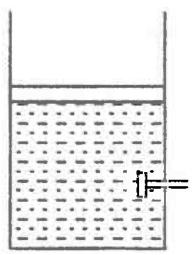
(a) Find the current that flows through the 2 Ω resistor as a function of time 't' for t > 0.

(b) What percentage of the work done by the 10 V cell is lost as heat from the 2Ω resistor, from t = 0 till infinity?

Q.2 A beam consisting of two wavelengths 8100 Å and 4500 Å is used to obtain interference fringes in a Young's double slit experiment. The distance between the slits is 2 mm and that between the plane of the slits and the screen is 100 cm.

(a) Find the least distance in millimeters from the central maxima on the screen where the bright fringes due to both the wavelengths coincide.

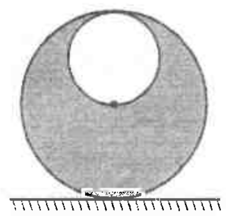
(b) Find the least distance in millimeters from the central maxima on the screen where the dark fringes due to both the wavelengths coincide.



Q.3 A cylinder contains a tight fitting piston of mass 2 kg and cross-sectional area 10 cm^2. Under the piston, there is 1 mole of a diatomic gas at 300 K initially. The walls of the cylinder are heat insulating and the piston is also thermally insulating. By means of an electrical heater, the gas is slowly given a heat = 1000 Joules. The upper end of cylinder is open to the atmosphere having atmospheric pressure = 10^5 Pascals. Neglect any frictional loss.

(a) By what distance does the piston shift up?

(b) What is the final temperature of the gas?

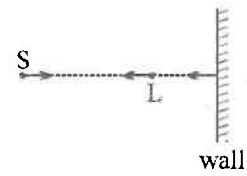


Q.4 A solid sphere with a hollow cavity (of radius R/2) having net mass m and radius R is resting in equilibrium on a rough horizontal floor, as shown. The sphere is tilted slightly and released. Find the time period of subsequent oscillations assuming that the sphere's surface does not slip over the floor.

Q.5 Two monochromatic and coherent point sources of light, S_1 and S_2 of wavelength 4000 Å, are placed at a distance 4 mm from each other. The line joining the two sources is perpendicular to a screen. The distance of the mid-point of S_1S_2 from the screen is $D = \sqrt{2}$ m. Find the radius (non-zero) of the smallest bright ring on the screen, using valid assumptions.

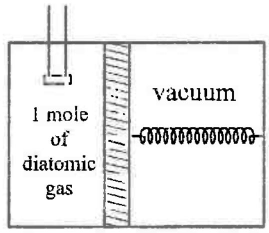
Q.6 A glass sphere of radius R has a point isotropic source of monochromatic light of wavelength λ. The thickness of the glass wall is 't' ($<< R$). The inner surface of the sphere is painted black so that it absorbs all the radiation incident on it. Find the maximum power of the source such that the sphere does not rupture due to the radiation pressure. Rupture stress of glass = σ.

Q.7 In the figure shown, the sonic source of frequency 200 Hz is moving with a speed = 10 m/s. Find the beat frequency as heard by the listener L, who is himself moving with speed = 5 m/s. The reflecting wall is moving with a speed = 15 m/s. A wind is also blowing to the right with a speed = 5 m/s. Speed of sound in still air = 340 m/s.

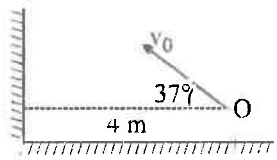


Q.8 A sphere of mass 'm' collides elastically with another stationary sphere of mass 'm/2' obliquely. Both the spheres are smooth and there are no external forces acting on them. Solve the equations of collision and find the maximum angle through which the sphere of mass 'm' can be deflected w.r.t. its original direction.

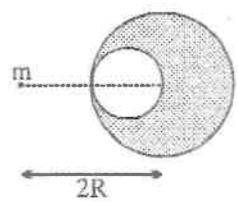
Q.9 A thermally insulated cylinder is divided into two parts by a heat insulating tight piston, which can move freely in the cylinder without friction. The left part of the cylinder contains one mole of an ideal diatomic gas and the right part is evacuated. The piston is connected to the right wall of the cylinder through a spring whose natural length is equal to the total length of the cylinder. The electrical heater is switched on for some time so that the gas temperature increases and the piston shifts slowly to the right. What percentage of the heat supplied by the heater goes in compressing the spring? Neglect the heat capacity of the piston or the cylinder.



Q.10 A ball is thrown from a point O with some speed v_0 at an angle of 37° with the horizontal, such that the ball bounces from the vertical wall and returns to O. For the bounce, the coefficient of restitution is 5/8. What must be the value of v_0? $g = 10\ m/s^2$.



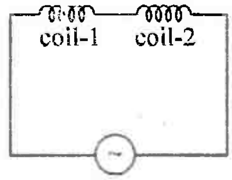
Q.11 A spherical body of mass M and radius R has a spherical cavity of radius R/2 inside it, as shown. The center of the cavity O is displaced from the geometric center of the sphere C by a distance R/2. A tiny body of mass m ($<< M$) is placed at a distance 2R from the geometric center of the first body.



(a) Find the force of gravitational attraction on the tiny body.

(b) If the tiny body is released from rest, with what velocity will it hit the surface of the spherical body?

Q.12 The circuit shown is fed by an a.c. source having emf = (15 V) sin 200t, where time t is in seconds. Coil-1 has a resistance = 3 Ω and inductance 20 mH, while coil-2 has a resistance = 6 Ω and inductance 40 mH. Find the voltages across the two coils, V_1 and V_2, as functions of time, t.



Q.13 A certain radionuclide is getting formed in some reactor at a constant rate = q (number per second). It undergoes alpha decay with half life T. At the moment t = 0, there are ($4qT/\ln 2$) number of radionuclide in the reactor.

(a) Find the number of radionuclide 'N' in the reactor at any later time $t > 0$ and plot a graph of N versus t.

(b) Find the number of alpha particles emitted till t = 2T.

Q.14 In a modified Young's double slit experiment, there are three identical parallel slits S_1, S_2 and S_3. A coherent monochromatic beam of wavelength 700 nm, having plane wavefronts, falls on the slits, as shown. The intensity of the central point O on the screen is found to be 7×10^{-4} W/m^2. The distance $S_1S_2 = S_2S_3 = 0.7$ mm.

(a) Find the intensity on the screen at O if S_1 and S_3 are covered.

(b) Find the intensity on the screen at O if only S_3 is covered.

(c) All three slits are now uncovered and a transparent plate of thickness 1.4 μm and refractive index 1.25 is placed in front of S_2. Find the intensity at point O.

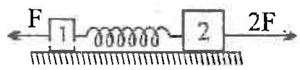
Q.15 A jeep is moving at a certain moment with velocity = 10 m/s. The acceleration of the jeep is 'a'. A man sitting in the jeep throws a ball with initial velocity = 20 m/s, at an angle of 53° with the horizontal, both w.r.t. himself. The motion of the jeep is in the same direction and vertical plane as the motion of the ball. Given: sin 53° = 4/5, cos 53° = 3/5. Neglect air resistance.

(a) Find the actual initial speed of the ball relative to an earth observer.

(b) What should be the acceleration 'a' of the jeep so that the man is able to catch the ball?

(c) What is the farthest distance of the ball from the man, as perceived by him, in part (B)?

Q.16 Two blocks, 1 & 2, of masses m and 4m, interconnected by a massless spring of spring constant k, and are resting on a frictionless horizontal floor. Forces F and 2F start acting on the blocks, at t = 0, as shown.

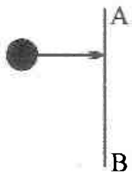


(a) Write the earth frame work-energy theorem for the system, in terms of speeds v_1 and v_2, and displacements x_1 and x_2 of the two blocks.

(b) Find the maximum elongation of the spring during the motion of the two blocks, if F = 5mg.

(c) Find the maximum speed of block-1 in the center of mass frame, if F = 5mg.

Q.17 A uniform and thin rod AB of mass 5m and length L is kept stationary on a frictionless horizontal surface. At a certain moment, a tiny ball of mass m, moving with a horizontal velocity = v_0 collides inelastically with the rod, at a point whose distance from end A of the rod is z. The direction of v_0 is perpendicular to the rod, as shown. The coefficient of restitution for collision is 3/4. Just after the collision, let v_2 = velocity of the center of rod (rightwards), v_1 = velocity of the ball, assumed leftwards and ω = angular velocity of the rod.



(a) Write the condition for coefficient of restitution = 3/4 in terms of relevant parameters

(b) It is found that the velocity of B just after the collision is zero. Find z.

(c) Assuming the condition of part (B), calculate the percentage of energy lost during the collision.

Q.18 A gaseous mixture initially at 300 K and 2×10^5 N/m^2 pressure contains 6 g of hydrogen and 8 gm of Helium. The mixture is expanded to four times its original volume, through an isobaric heating process. Then, it is isochorically cooled until its temperature again becomes 300 K. After that, the gas mixture is isothermally compressed to its original volume.

(a) Find the ratio of molar specific heats = γ of the mixture.

(b) Plot the process in P-V and P-T indicator diagrams, showing all values of P & T.

(c) Find the efficiency of the entire cycle (take ln 2 = 0.7)

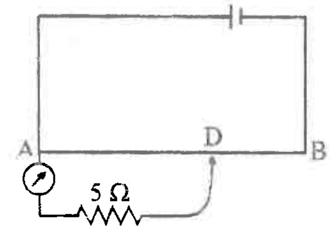
Q.19 Two radio stations broadcast their programmes at the same amplitude A, but at slightly different frequencies ω_1 and ω_2, where $\omega_1 - \omega_2 = 1000$ Hz. A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity > $2A^2$.

(a) Find the time interval between the successive maxima of the intensity of the signal received by the detector.

(b) Find the time for which the detector remains idle in each cycle of the intensity of the signal.

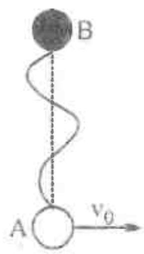
Q.20 A long wire PQR is made by joining two wires PQ and QR of equal radii. Their lengths and masses are respectively: 4.8 m and 0.06 kg; 2.56 m & 0.2 kg. The tension is 80 N. A sinusoidal wave pulse of amplitude 3.5 cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave pulse. Calculate the time taken by the pulse to reach the end R and the amplitude of reflected and transmitted wave pulses at Q.

Q.21 In the circuit shown, the potentiometer wire AB has a length = 100 cm and total resistance 10 Ω. What should be the distance of the jockey from point A so that the reading of the ammeter is 0.5 A? The coil resistance of the ammeter is 1 Ω. The cell at the top has an emf = 15 Volts and internal resistance 1 Ω.



Q.22 A soap bubble of radius r is blown at the end of a capillary of length l and of internal radius R. Surface tension of soap solution is T and coefficient of viscosity of air is η. The volume of air flowing per second through the capillary is given by $\frac{\pi P R^4}{8\eta l}$, where P is the excess pressure on soap bubble. Find the lifetime of the soap bubble.

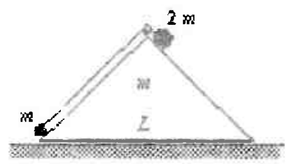
Q.23 Two small balls A and B are interconnected by an inextensible string of length L. Mass of ball A = m, mass of ball B = 2m. The balls are resting on a frictionless horizontal surface, with the distance between them = 3L/5. In this position, ball A is suddenly given a horizontal velocity v_0, perpendicular to the line joining the two balls.



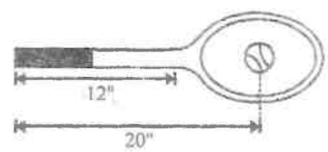
(a) Find the speed of ball B just after the string becomes taut.
(b) Find the impulse of the tension in string when the string becomes taut.
(c) Find the steady tension in string much after the string has become taut.

Q.24 A wooden log of mass *m* with a cross-section shaped like an equilateral right-angled triangle can slide on a horizontal surface without friction. Two point-like bodies of masses *m* and 2*m*, tied to each other using a thread, are placed onto the log as shown in the figure. The length of the base of the log is *L*=54 cm. Friction and the masses of the thread and the pulley are negligible. The bodies are released at a certain moment.

(a) What distance does the wooden log cover until the body of mass 2*m* reaches its bottom?
(b) Determine the speed of the bodies and that of the wooden log when the body of mass 2*m* reaches the bottom of the log.

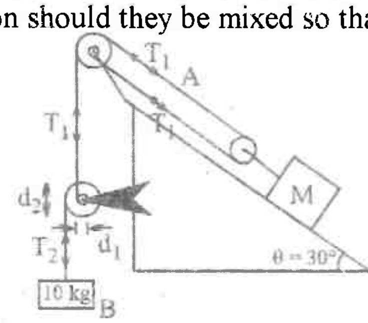


Q.25 In a tennis racket, the c.m. is 12 inches from the end of the handle. The radius of gyration about an axis through the c.m. as shown in the figure is 8 inches. If the tennis ball is hit at a distance of 20 inches from the end of the handle, where should the player hold his racket so as not to feel any translational force when hitting the ball?

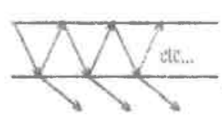


Q.26 We have two liquids of different densities. A force of 1.36 N can hold the same piece of metal in one of them, and of 0.82 N in the other. In what volume proportion should they be mixed so that the holding force is exactly 1 N?

Q.27 A cart on an inclined plane of angle θ = 30° is balanced as shown by a weight of mass 10 kg. The cord A is wound on a drum of diameter d_1, which is on the same shaft as a drum of diameter $d_2 = 3d_1$, on which is wound cord B. What is the mass M of the cart?

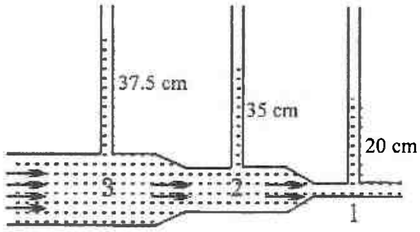


Q.28 **Through the Looking Glass**: A narrow beam of light has entered a large thin lass plate. Each refraction is accompanied by reflection of k = 30% of the beam's energy. What fraction of the light energy is transmitted through the plate?



Q.29 **Lake Placid**: A radio receiver is set up on a mast in the middle of a calm lake to track the radio signal from a satellite orbiting the Earth. As the satellite rises above the horizon, the intensity of the signal varies periodically. the intensity is at a maximum when the satellite is $\theta_1 = 3°$ above the horizon and then again at $\theta_2 = 6°$ above the horizon. What is the wavelength λ of the satellite signal? The receiver is h = 4.0 m above the lake surface.

Q.30 In the figure, water of density 1000 kg/m^3 flows through the pipe. The cross-section area at stations 1, 2 and 3 are 1 cm^2, 2 cm^2 and A cm^2, respectively. The thin vertical tubes that are connected to the pipe at these stations have water levels as indicated. Find the mass flow rate of water through the pipe and v_3. [Take g = 10 m/s^2]

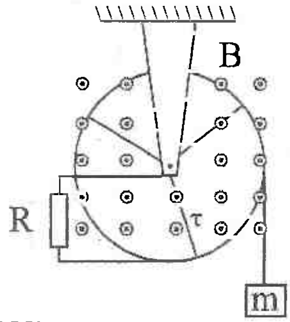


Q.31 A metal ring having three metallic spokes of lengths r=0.2 m is in a vertical plane and can spin around a fixed horizontal axis in a homogeneous magnetic field of a magnetic induction of B=0.5 T. The lines of magnetic field are perpendicular to the plane of the metal ring. Between the axis of the metal ring and its perimeter we connect a consumer of a resistance of 0.15 with the help of two sliding contacts. We fix a thread of negligible mass to the rim of the ring and wind it several times around the ring and to its end we fix a body of a mass of 20 g. At a given moment we release the body of mass m. The friction is negligible everywhere, the resistance of the ring, the spokes and the connected wiring is also negligible.

(a) What is the torque exerted on the ring with the spokes by the magnetic forces when the body of mass m is moving with a constant velocity?

(b) What current is flowing through the consumer when the velocity of the body of mass m is 3 m/s?

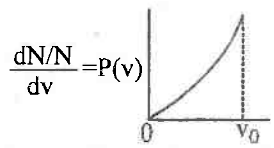
(c) What is the highest velocity of the body of mass m?



Q.32 Figure shows a hypothetical speed distribution for particles of a certain gas: P (v) = Cv^2 for $0 < v < v_0$ and P(v) = 0 for $v > v_0$.

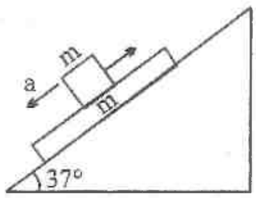
(a) Show that $C = 3/v_0^3$,

Find (b) the average speed of the particles, and (c) their rms speed.



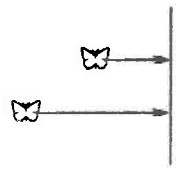
Q.33 A neutron moving with a kinetic energy = 65 eV collides head-on and inelastically with a singly ionized helium atom at rest (in its ground state). Take the ionization energy of hydrogen atom = 13.6 eV. Also, mass of Helium atom is four times that of a neutron. If the helium ion gets de-excited subsequently by emitting radiation, calculate the possible energies of the emitted photon(s) in eV.

Q.34 A board of mass m is placed on a frictionless inclined plane that makes an angle θ = 37° with the horizontal. A block of same mass is placed on the board and is given a quick push up the board with initial velocity v = 8 m/s. Find the distane d covered by the block by the time its velocity drops to v/2. The board does not move relative to the plane.



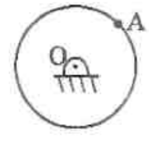
Q.35 A 20 mH inductor is connected in series with a charged capacitor of capacitance 2 μF, having initial charge = 10 mC. After how much minimum time will the energy in the capacitor become half of its initial value? Leave answer in terms of π.

Q.36 A uniform and slender rod of mass 2m and length L is lying on a frictionless horizontal surface. Two insects, of mass m each, moving horizontally with velocities v and 2v hit the rod simultaneously and symmetrically and stick to it.



The initial velocities of the insects are perpendicular to the rod, as shown. The distance of each insects's hit-point from the center of the rod is L/6. Just after hitting the rod, each insect starts walking along the rod, away from its center, with constant speed = v relative to the rod. As the rod rotates and moves, the insects finally reach the ends. Find the total angle rotated by the rod till this moment in radians.

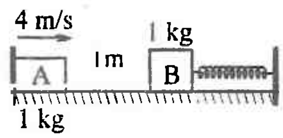
Q.37 A thin uniform circular disc of radius R and mass m is hinged about its center point O, so that it is free to rotate about a fixed horizontal axis through O. The plane of the disc is vertical. A small body A, of mass m/2, is fixed at the rim of the disc, as shown. Initially, the line OA makes an angle of 60° with the vertical. The disc is now released from rest.



(a) Find the acceleration of point A just after release.

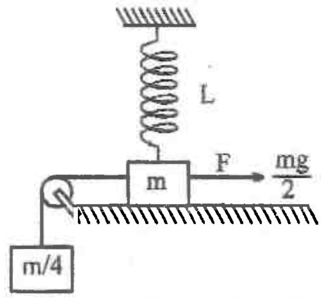
(b) Find the magnitude of horizontal and vertical reaction forces: F_{hor} and F_{ver} on the hinge, just after the disc is released.

Q.38 In the figure shown, the spring constant is $16\pi^2$ N/m and its right end is fixed to a vertical wall. The floor is smooth. A block of mass 1 kg is initially at a distance of 1 m from the other 1 kg block. The left block, touching a vertical wall, is imparted a velocity = 4 m/s towards the other block. All collisions are elastic. Find the time period of this oscillatory system.



Q.39 A ring of radius r = 1 m is placed on the top of an inclined plane and released from rest. The inclined plane makes an angle of 30° with the horizontal. The coefficient of friction between the ring and the incline is 0.2. Find the distance travelled by the centre of the ring by the time it completes one revolution, as it rolls down the incline.

Q.40 In the figure shown, a constant horizontal force F = mg/2 starts acting on the block of mass m, from the position shown. The spring is undeformed in the position shown and has a narual length L, while the blocks are initially stationary. The spring constant is unknown. The surface is frictionless. The mass of the hanging block is m/4, while the pulley is massless and frictionless.



(a) Find the initial acceleration of the block of mass.

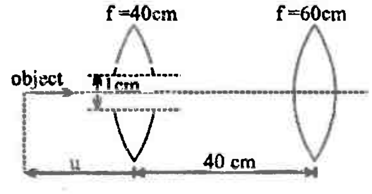
(b) Write the work-energy equation for the system consisting of the two blocks, and the spring, for any general value of θ = angle which the spring makes with the vertical.

(c) The maximum displacement of the bigger block is found to be $L\sqrt{3}$. Based on this information, find the spring constant.

Q.41 A lift is moving up with a constant retardation = 2 m/s^2. When its upward velocity is 5 m/s, a boy in the lift tosses a coin, imparting it an upward initial velocity = 3 m/s, with respect to himself His fingers at the moment of toss are midway between the floor and ceiling, whose total height is 2.0 m. After how much time will the coin hit the floor or roof of the lift? Also find the distance travelled by the coin and its displacement in the earth frame till then. [Take g = 10 m/s^2]

Q.42 At a distance of 20 m from a point isotropic source of sound, the loudness level is 30 dB. Neglecting damping of sound, find the loudness level at a distance of 10 m from the source and the distance where the sound is not audible by humans.

Q.43 In the figure shown, find the relative speed of approach/ separation of the two final images formed after the light rays pass through the lens on the far right, at the moment when u = 30 cm. The speed of object = 4 cm/s. The two lens halves are placed symmetrically w.r.t the moving object.



Q.44 **HEAT CAPACITY DETERMINATION OF A LIQUID USING CALORIMETER :**

Figure shows the Regnault's appratus to determine the specific heat capacity of a unknown liquid. A solid sphere of known specific heat capacity s_1 having mass m_1 and initial temperature θ_1, is mixed with the unknown liquid filled in a calorimeter. Let masses of liquid and calorimeter are m_2 and m_3 respectively, specific heat capacities are s_2 and s_3 and initially they were at room temperature θ_2. When the hot sphere is dropped in it, the sphere looses heat and the liquid calorimeter system takes heat. This process continues till the temperature of all the elements becomes same (say θ).

Heat lost by hot sphere = $m_1s_1(\theta_1-\theta)$

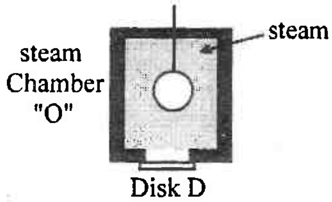
Heat taken by liquid & calorimeter = $m_2s_2(\theta-\theta_2) + m_3s_3(\theta-\theta_2)$

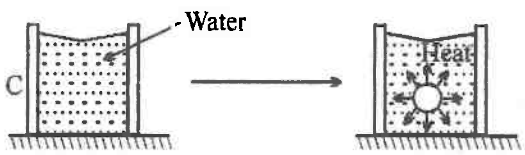
If there were no external heat loss

Heat given by sphere = Heat taken by liquid – calorimeter system

$$m_1s_1(\theta_1-\theta) = m_2s_2(\theta-\theta_2) + m_3s_3(\theta-\theta_2)$$

Get $$s_2 = \frac{m_1s_1(\theta_1-\theta)}{m_2(\theta-\theta_2)} - \frac{m_3s_3}{m_2}$$





Calorimeter

By measuring the final (steady state) temperature of the mixture, we can estimate s_2 : specific heat capacity of the unknown liquid. To give initial temperature (θ_1) to the sphere, we keep it in steam chamber ("O"), hanged by thread. Within some time (say 15 min) it achieves a constant temperature θ_1. Now the calorimeter, filled with water (part C) is taken below the steam chamber, the wooden removable disc D is removed, and the thread is cut. The sphere drops in the water calorimeter system and the mixing starts.

If specific heat capacity of liquid (s_2) were known and that of the solid ball (s_1) is unknow then

we can find $$s_1 = \frac{(m_2s_2 + m_3s_3)(\theta-\theta_2)}{m_1(\theta_1-\theta)}$$

(a) In the exp. of finding specific heat capacity of an unknow sphere (s_2) mass of the sphere and calorimeter are 1000 gm and 200 gm respectively and specific heat capacity of calorimeter is equal to 1/2 cal/gm/°C. The mass of liquid (water) used is 900 gm. Initially both the water and the calorimeter were at room temperature 20.0°C while the sphere was at temperature 80.0°C initially. If the steady state temperature was found to be 40.0°C, estimate specific heat capacity of the unknow sphere (s_2). (Use s_{water} = 1 cal/g/°C)

Also find the maximum permissible error in specific heat capacity of unkown solid.

(b) What should be final temperature so that the error in s should ne minimum?

Q.45 END CORRECTIONS IN METER BRIDGE

In meter bridge circuit, some extra length of wire called end corrections should be included at ends for accurate result.

Suppose null point is obtained at l_1, then

$$\frac{Q_1}{Q_2} = \frac{l_1 + \alpha}{100 - l_1 + \beta}$$

When known resistances are interchanged then balancing length is at l_2.

$$\frac{R_2}{R_1} = \frac{l_2 + \alpha}{100 - l_2 + \beta}$$

The end corrections calculated from above readings are used to modify observation

If 100 Ω & 200 Ω values of known resistance is used to give null deflection at l_1 = 33.0 cm & on interchanging the known resistances the null deflection is found at 67.0 cm. Find the value of end correction.

Q.46 INDEX ERROR IN OPTICAL BENCH

In u-v method the distance between object or image from the pole of mirror or les is required. Practically the position of holder when read from scale do not exactly give object or image distance. This mismatch is constant for every observation. To determine index error a needle (usually usedfor knitting) of known length is placed horizontally between the pole & object needle. The length of knitting needle gives actual object distance while the separation between holder index is read from the scale. Which becomes observed distance so index error (or excess reading) is e = Observed distance – Actual Distance

For index correction the e is subtracted from observed reading to get correct reading.

(a) When a knitting needle of length 20.0 cm is adjusted between pole and object needle, the separation between the indices of object needle and mirror was observed to be 20.2 cm. Find the index correction for u.

(b) When the same knitting needle is adjusting between the pole and the image needle, the separation between the indices of image needle and mirror was found to be 19.9 cm. Find the index error for v.

(c) In some observation, the observed object distance (Separation between indices of object needle and mirror) is 30.2 cm, and the observed image distance is 19.9 cm. Using index correction from previous two equations, estimate the focal length of the concave-mirror.

Q.47 A conducting sphere of radius a is surrounded by another spherical thin conducting shell of radius b. The space between them is filled with dielectric material of conductivity σ and dielectric constant k. The charge Q_i and Q_2 are given to the inner and outer shell at time t = 0. Find charge on outer shell at time t.

Q.48 The amplitude of the electric field in an electromagnetic wave of frequency $\omega = 2.0 \times 10^{16}\ s^{-1}$ changes with times as $E(t) = k(1 + \cos \Omega t)$, where k is a constant and $\Omega = 1.8 \times 10^{15}\ s^{-1}$. Would such a wave cause ionization of hydrogen atoms? If yes,what is the energy of the ejected electrons E_e? Assume that atoms absorb light as photons. The ionization energy of hydrogen gas is E_i = 13.6 eV. the Planck constant h – 1.05 J × s.

Q.49 An air-filled parallel-plate capacitor with the plate area A is connected to a battery with an emf E and small internal resistance. One of the plates vibrates so that the distance between the plates varies as $d = d_0 + a \cos \omega t$ ($a \ll d_0$). The capacitor break down when the instantaneous current in the circuit reaches the value of I. Find the maximum possible amplitude of vibrations a.

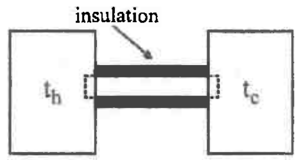
Q.50 Two simple pendulums of length L each are attached to the ceiling. The small balls attached to the strings have equal masses m. The weights are connected by a very light relaxed rubber band (not a spring) with the force constant k. At a certain moment, each ball is given a light quick push as shown, resulting in equal initial speeds. Find the period T of the ensuing motion.

Q.51 A proton (m, e) and an alpha particle (4m, 2e) approach each other from a large distance. Initially, their velocities are the same (v). Find the minimum separation r between the particles.

Q.52 A wooden cube with a side of d = 0.10 m is placed on a horizontal support. A bullet of mass m = 0.010 kg is shot vertically up through the support and through the cube. As the bullet passes through the cube, its speed decreases uniformly from v = 120 m/s to u = 115 m/s. Estimate the minimum mass M of the cube that would allow it not to lose contact with the support.

Q.53 In a strictly scientific experiment, a student athlete throws rocks out the window in all directions. All rocks have the same initial speed v. It turns out that all rocks' landing velocities make angles θ or greater with the horizontal. Find the height h of the window above the ground.

Q.54 An insulated container is filled with a mixture of water and ice at $t_c = 0°C$. Another container is filled with water that is continuously boiling at $t_h = 100°C$. In a series of experiments, the containers are connected by various thick rods that pass through the walls of the containers (refer diagram). The rod is insulated in such a way that there is no heat loss to surroundings. In experiment 1, a copper rod is used and the ice melts in $T_1 = 20$ min.
In experiment 2, a steel rod of the same cross section is used and the ice melts in $T_2 = 60$ min. How long would it take to melt the ice if the two rods are used "in series"?



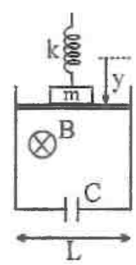
Q.55 How can you measure the resistance of an unknown resistor r with an ammeter and a voltmeter if you don't know the internal resistances of these devices? A voltage source is available.

Q.56 A dubmbell consists of a light rod of length r and two small masses m attached to it. The dumbbell stands vertically in the corner formed by two frictionless planes. After the bottom end is slightly moved to the right, the dumbbell begins to slide. Find the speed u of the bottom end at the moment the top end loses contact with the vertical plane.

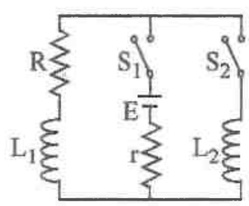


Q.57 Find the maximum power of a heating element that can be constructed from a piece of wire that has a resistance of 536 Ω. The element is to be powered by a constant voltage of V = 110 V. The current through the wire cannot exceed 2 A.

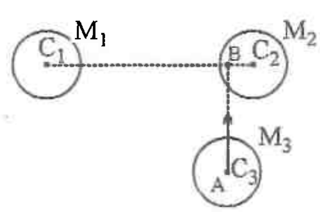
Q.58 A heavy block is attached to the ceiling by a spring that has a force constant k. A conducting rod is attached to the block. The combined mass of the block and the rod is m. The rod can slide without friction along two vertical parallel rails, which are a distance L apart. A capacitor of known capacitance C is attached to the rails by the wires. The entire system is placed in a uniform magnetic field B directed as shown. Find the period T of the vertical oscillations of the block. Neglect the electrical resistance of the rod and all wires.



Q.59 An electric circuit contains a battery with emf E and internal resistance r, two coils with inductances L_1 and L_2 and a resistor R, connected as shown. On the diagram, all shown parameters are given. Initially, both switches are open. Switch S_1 is then closed. After a while, switch S_2 is closed. What is the total charge Q that passes through the resistor after S_2 is closed?



Q.60 Figure shows three identical balls M_1, M_2 and M_3 each of radius 10 cm. The ball M_3 is given a certain velocity in the direction of AB such that after collision with M_2, it (M_3) has a head-on collision with the ball M_1. Find the distance BC_2 (in cm) where B lies on the line joining the centres of M_1 and M_2. The balls are assumed to be perfectly elastic. Given $C_1C_2 = 1$ m.



HINTS & SOLUTIONS
MATHEMATICS

1. $$L = \lim_{x\to 0}\left(\frac{1}{\ln(1+x)} - \frac{1}{\ln(x+\sqrt{1+x^2})}\right)$$

$$L = \lim_{x\to 0}\frac{\ln(x+\sqrt{1+x^2}) - \ln(x+1)}{x\cdot\frac{\ln(x+1)}{x}\cdot\ln(x+\sqrt{1+x^2})} = \lim_{x\to 0}\frac{\ln\left(\frac{x+\sqrt{1+x^2}}{1+x}\right)}{\frac{x\cdot\ln\left((x+\sqrt{1+x^2}-1)+1\right)(x+\sqrt{1+x^2}-1)}{(x+\sqrt{1+x^2}-1)}}$$

note that $\lim_{x\to 0}\frac{\ln\left((x+\sqrt{1+x^2}-1)+1\right)}{\left(x+\sqrt{1+x^2}-1\right)} \to 1$

hence $$L = \lim_{x\to 0}\frac{\ln\left(\left(\frac{x+\sqrt{1+x^2}}{1+x}-1\right)+1\right)\cdot\left(\frac{x+\sqrt{1+x^2}}{1+x}-1\right)}{x\cdot\left(\frac{x+\sqrt{1+x^2}}{1+x}-1\right)(x+\sqrt{1+x^2}-1)}$$

Note that $$\lim_{x\to 0}\frac{\ln\left(\left(\frac{x+\sqrt{1+x^2}}{1+x}-1\right)+1\right)}{\left(\frac{x+\sqrt{1+x^2}}{1+x}-1\right)} = 1$$

$\therefore$ $$L = \lim_{x\to 0}\frac{x+\sqrt{1+x^2}-1-x}{x(1+x)(x+\sqrt{1+x^2}-1)} = \lim_{x\to 0}\frac{\sqrt{1+x^2}-1}{x(\sqrt{1+x^2}+x-1)}$$ (as $\lim_{x\to 0}(1+x) = 1$)

$$L = \lim_{x\to 0}\frac{(\sqrt{x^2+1}-1)(\sqrt{x^2+1}+1)}{(\sqrt{x^2+1}+1)\cdot x(\sqrt{x^2+1}+x-1)}$$

$$= \frac{1}{2}\lim_{x\to 0}\frac{[(x^2+1)-1][\sqrt{x^2+1}-(x-1)]}{x\cdot(\sqrt{x^2+1}+x-1)\cdot[\sqrt{x^2+1}-(x-1)]}$$

$$= \lim_{x\to 0}\frac{1}{2}\frac{x\cdot 2}{(x^2+1)-(x-1)^2} = \lim_{x\to 0}\frac{x}{2x} = \frac{1}{2}$$

$\therefore$ $L = \frac{1}{2}$

hence $\frac{L+153}{L} = \frac{(1/2)+153}{(1/2)} = 1 + 2\cdot 153 = 1 + 306 = 307$ Ans.]

2. Let C: problem is solved correctly $P(C) = \frac{9 \cdot 10 + 10 \cdot 16}{300} = \frac{5}{6}$ ....(1)

W: problem is solved wrongly $P(W) = \frac{1}{6}$

C_1: She thinks that the problem is correct
W_1: She thinks that the problems is wrong

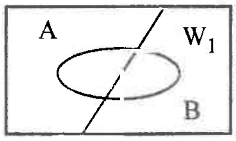
A : Problems from the university A; $P(A) = \frac{1}{3}$

B : Problems from the university B; $P(B) = \frac{2}{3}$

$P(W/W_1) = \frac{3}{4}$; $P(W_1/A) = \frac{1}{5}$; $P(C/W_1) = \frac{1}{4}$; $P(W_1/B) = \frac{1}{10}$

we have to find $P(W_1/C) = ?$

now $P(W_1/C) = \frac{P(W_1 \cap C)}{P(C)} = \frac{P(W_1) \cdot P(C/W_1)}{P(C)}$ ....(2)

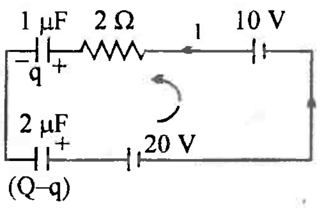


now $P(W_1) = P(A \cap W_1) + P(B \cap W_1)$
$= P(A) \cdot P(W_1/A) + P(B) \cdot P(W_1/B)$
$= \frac{1}{3} \cdot \frac{1}{5} + \frac{2}{3} \cdot \frac{1}{10} = \frac{2}{15}$

Hence from (1) and (2)

$$P(W_1/C) = \frac{(2/15) \cdot (1/4)}{(5/6)} = \frac{1}{30} \cdot \frac{6}{5} = \frac{1}{25} \Rightarrow p + q = 1 + 25 = 26 \textbf{ Ans.]}$$

PHYSICS

1.(a)


where Q = 40 μC, the charge on 2μF just before closing the switch 2.

By kirchhoff's law

$$\left(\frac{Q-q}{2}\right) - 20 + 10 - 2I - q = 0$$

$$10 - \frac{3q}{2} = 2I = 2\frac{dq}{dt}; \quad \therefore \quad 3q - 20 = -4\frac{dq}{dt}; \quad \therefore \quad \frac{dq}{3q-20} = -\frac{1}{4}dt$$

integrating both sides $\int_0^q \frac{dt}{3q-20} = \frac{1}{4}\int_0^t dt = \frac{1}{3} ln\left|\frac{3q-20}{-20}\right| = -\frac{1}{4}t$

$\therefore$ on solving $q = \frac{20}{3}\left(1 - e^{-3t/4}\right)\mu C$

$\therefore \quad I = \frac{dq}{dt} = 5e^{-3t/4}$ amp

(b) Work done by 10 V battery = $\frac{20}{3} \times 10^{-6} \times 10 = \frac{20}{3} \times 10^{-5}$ J

Heat lost by 2Ω resistor = $\int_0^{\infty} I^2(2)\,dt = 50\int_0^{\infty} e^{-3/2}\,dt = \frac{10}{3}\times 10^{-5}$ J

∴ percentage of work done by 10V battery lost in the form of heat = $\frac{\left(\frac{10}{3}\times 10^{-5}\right)}{\left(\frac{20}{3}\times 10^{-5}\right)} \times 10\% = 50\%$]

2.(a) $y = \frac{m\lambda D}{d} = \frac{n\lambda D}{d}$ for coincidence of maxima

$8100\ m = 4500\ n$

$\frac{n}{m} = \frac{9}{5}$

$y = \frac{9\times 4500\times 10^{-10}\times 1}{2\times 10^{-3}} = 2.025$ mm

(b) $\left(m+\frac{1}{2}\right)\times 8100 = \left(n+\frac{1}{2}\right)\times 4500;\ \frac{\left(n+\frac{1}{2}\right)}{\left(m+\frac{1}{2}\right)} = \frac{9}{5} \Rightarrow n = 4;\ m = 2$

$y = \left(4+\frac{1}{2}\right)\times \frac{4500\times 10^{-10}}{2\times 10^{-3}} = 1.0125$ mm Ans.]

3. The whole process is isobaric with pressure = $P_0 + \frac{mg}{A} = \left(10^5 + \frac{2\times 10}{10\times 10^{-4}}\right)$ N/m² = 1.2×10^5 N/m²

$\Delta Q = nC_p\Delta T$

∴ $1000 = 1 \times \frac{7}{2} \times \frac{25}{3} \times \Delta T$

$\Delta T = \frac{6000}{7\times 25} = \frac{240}{7}$ K

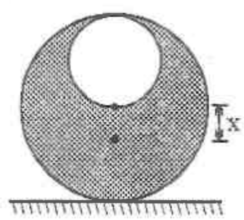
(a) $\Delta W = nR\Delta T = 1 \times \frac{25}{3} \times \frac{240}{7}$ J $= \frac{2000}{7}$ J $= 285.7$ J

$P\Delta V = \Delta W \Rightarrow P \times A \times \Delta h = \Delta W$

∴ $\Delta h = \frac{50}{21}$ m

(b) Final temperature = (300 + (240/7)) K = $\frac{2340}{7}$ K]

4. If x is the position of centre of mass below the centre of sphere

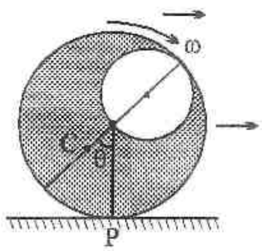


$\frac{xm - \frac{R}{2}\cdot\frac{m}{7}}{\frac{8m}{7}} = 0 \Rightarrow x = \frac{R}{14}$

Total energy = $mg\left(R - \frac{R}{14}\cos\theta\right) + \frac{1}{2}I_P\omega^2$ ....(1)

From parallel axis theorem

$$I_P \approx I_0 - m\left(\frac{R}{14}\right)^2 + m\left(\frac{13R}{14}\right)^2 \quad (\theta \text{ is small});$$



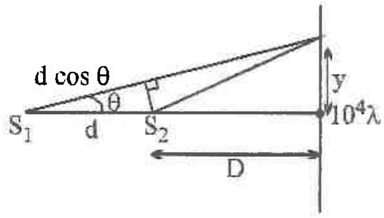
Also $I_0 = \frac{2}{5}\left(\frac{8m}{7}\right)R^2 - \frac{7}{5}\left(\frac{m}{7}\right)\left(\frac{R}{2}\right)^2$

differentiating equation (1)

$$0 = -mg\frac{R}{14}(-\sin\theta)\frac{d\theta}{dt} + \frac{1}{2}\left(2\omega\frac{d\omega}{dt}\right)I_P$$

$$\frac{d\omega}{dt} \approx \frac{mgR}{14I_P}Q \quad]$$

5. $\frac{y}{D} = \tan\theta$



$\Delta x = d\cos\theta$

$(10^4\lambda - \lambda) = 10^4\lambda\cos\theta$

$\cos\theta = 1 - \frac{1}{10^4};$

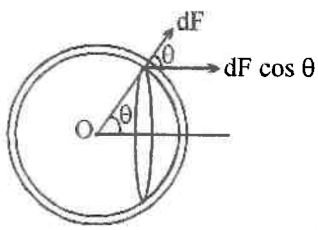
$2\sin^2(\theta/2) = \frac{1}{10^4}$ $\quad(\cos\theta = 1 - 2\sin^2(\theta/2))$; $\sin(\theta/2) = \frac{1}{(\sqrt{2})100};$

$\theta = \frac{\sqrt{2}}{100} = \frac{y}{D};$ $\qquad y = \frac{D\sqrt{2}}{100}\text{ m} = 2\text{ cm}$ Ans.]

6. $r = R\sin\theta$

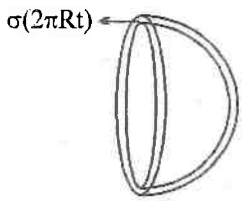
$\frac{P_0}{4\pi R^2} \times (2\pi R\sin\theta)R\,d\theta = dE$

$\frac{P_0\sin\theta\,d\theta}{2} = (dn)\frac{hc}{\lambda}$



$dn = \frac{P_0\sin\theta\,d\theta}{2hc}$

$dF\cos\theta = \frac{h}{\lambda} \times \left(\frac{P_0\lambda\sin\theta\,d\theta}{2hc}\right)\cos\theta$



$\int dF_{eff} = \frac{P_0}{2c}\int_0^{\pi/2}\sin\theta\cos\theta\,d\theta$

$F_{eff} = \frac{P_0}{2c} \times \frac{1}{2} = \frac{P_0}{4c}$

$\sigma 2\pi Rt = \frac{P_0}{4c}$

$P_0 = 8\pi\sigma Rtc \quad]$

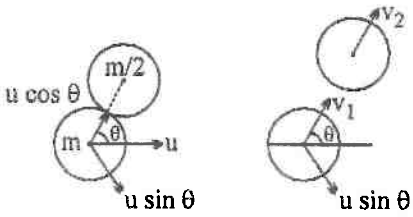
7. $f_1 = 200\left(\frac{340+5+5}{340+5-10}\right) = \frac{350\times200}{335}$ $\qquad f_2' = 200\left(\frac{340+5+15}{340+5-10}\right) = \frac{200\times360}{335}$

$f_2 = 200 \times \frac{360}{335}\left(\frac{340-5-5}{340-5-15}\right) = 200 \times \frac{360}{335} \times \frac{330}{320}$

$f_2 - f_1 = 200 \times \frac{360}{335} \times \frac{330}{320} - 200 \times \frac{350}{335} = \frac{200}{335}\left[\frac{360\times330}{320} - 350\right] = \frac{200}{335}\left[\frac{360\times33}{32} - 350\right]$

$f_2 - f_1 \approx 12.68$ Hz]

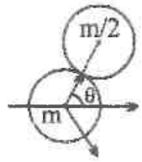
8. $m\,u\cos\theta = \frac{m}{2}v_2 + mv_1$



$\frac{v_2 - v_1}{0 - u\cos\theta} = -1$

$v_2 - v_1 = u\cos\theta$

$\frac{v_2}{2} + v_1 = u\cos\theta$



$v_2 = \frac{4u\cos\theta}{3}$

$v_1 = \frac{u\cos\theta}{3}$

$\phi = \tan^{-1}\left(\frac{u\cos\theta}{3u\sin\theta}\right)$; $\phi = \tan^{-1}\left(\frac{\cot\theta}{3}\right)$

$\beta = \frac{\pi}{2} - \theta - \phi$

$\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{\cot\theta}{3}\right) - \theta$; $\tan^{-1}\left(\frac{\cot\theta}{3}\right) = \frac{\pi}{2} - (\beta - \theta)$

$\frac{\cot\theta}{3} = \cot(\beta+\theta)$

$\frac{\cot\theta}{3} = \frac{\cot\beta\cot\theta - 1}{\cot\beta + \cot\theta}$

$\cot\beta\cot\theta + \cot^2\theta = 3\cot\beta\cot\theta - 3$

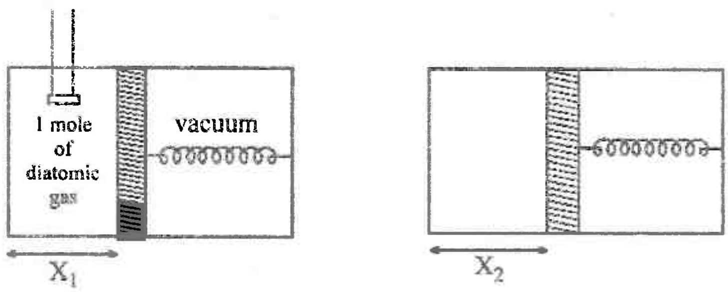
$\cot\beta = \frac{1}{2}\frac{1}{\tan\theta} + \frac{3\tan\theta}{2}$

$\Rightarrow \cot\beta$ is min. at $\tan\theta = \frac{1}{\sqrt{3}}$

hence β is max. at $\theta = 30°$]

9. $V_1 = AX_1$, $V_2 = AX_2$

$P_1 = \frac{kX_1}{A}$, $P_2 = \frac{kX_2}{A}$



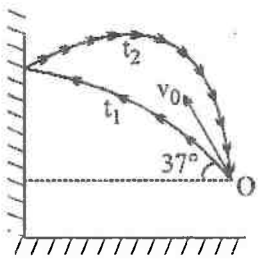
$$\Delta W = \int_{X_1}^{X_2} kXdx = \frac{K}{2}(X_2^2 - X_1^2)$$

$$\Delta Q = \Delta U + \Delta W = nC_v dT + \Delta W = \frac{5}{2}R(T_2 - T_1) + \Delta W$$

$$\Delta Q = \frac{5}{2}(RT_2 - RT_1) + \Delta W = \frac{5}{2}(P_2V_2 - P_1V_1) + \Delta W = \frac{5}{2}(kX_2^2 - kX_1^2) + \frac{k}{2}(X_2^2 - X_1^2)$$

$$\eta = \frac{\Delta W}{\Delta Q} \times 100 = \frac{(k/2)(X_2^2 - X_1^2)}{(5/2)(kX_2^2 - kX_1^2) + (k/2)(X_2^2 - X_1^2)} \times 100 = \frac{100}{6}\% \quad]$$

10. $t_1 = \frac{u}{v_0 \cos 37°}$, $t_2 = \frac{u}{e v_0 \cos 37°} = \frac{u}{5/8 \times v_0 \times 4/5}$



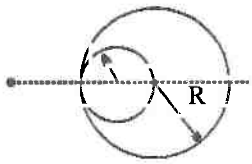
$$T = t_1 + t_2 = \frac{5}{v_0} + \frac{8}{v_0} = \frac{13}{v_0}$$

$$\frac{2v_0 \sin 37°}{g} = \frac{13}{v_0}, \quad \frac{2v_0 \times 3/5}{10} = \frac{13}{v_0}$$

$$v_0 = 5\sqrt{\frac{13}{3}} \text{ m/s} \quad]$$

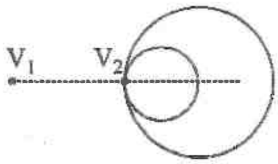
11.(a) $M = \rho \frac{4}{3}\pi \frac{7R^3}{8}$; $\quad M_{total} = \rho \frac{4}{3}\pi R^3 = \frac{8M}{7}$; $\quad M_{removed} = \rho \frac{4}{3}\pi \frac{R^3}{8} = \frac{M}{7}$

$$F = F_1 - F_2 = \frac{GM_{total}m}{(2R)^2} - \frac{GM_{removal}m}{\left(\frac{3R}{2}\right)^2} = \frac{2GMm}{9R^2}$$



(b) If V_1 and V_2 gravitational potentials, v is final speed

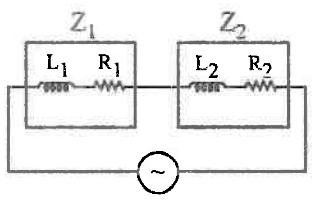
$\Rightarrow \quad v = \sqrt{2(V_1 - V_2)}$



where $V_1 = \left(-\frac{GM_{total}}{2R}\right) - \left(-\frac{GM_{removed}}{\frac{3R}{2}}\right)$; $V_2 = \left(-\frac{GM_{total}}{R}\right) - \left(-\frac{GM_{removed}}{R/2}\right)$

putting the value of V_1 and V_2 and solving we get, $\quad v = \sqrt{\frac{16GM}{21R}}$]

12.



$R_1 = 3\Omega$
$L_1 = 20 \times 10^{-3}$ H
$R_2 = 6\Omega$
$L_2 = 40 \times 10^{-3}$ H

$$Z_1 = \sqrt{R_1^2 + (\omega L_1)^2} = \sqrt{3^2 + 4^2} = 5$$

$$Z_2 = \sqrt{R_2^2 + (\omega L_2)^2} = \sqrt{6^2 + 8^2} = 10$$

$$Z = \sqrt{(R_1 + R_2)^2 + \omega(L_1 + L_2)^2} = \sqrt{9^2 + 12^2} = 15$$

$$I = \frac{e_0}{Z}\sin(200t - \phi) = \frac{15}{15}\sin(200t - \phi)$$

$I = \sin(200t - \phi)$ where $\cos\phi = \frac{R_1 + R_2}{Z} = \frac{9}{15} = \frac{3}{5}$

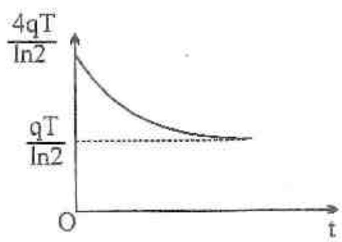
Now, $V_1 = I_0 Z_1 \sin(200\,t - \phi + \phi_1)$

$= 5\sin(200t)$ $[\because \phi = \phi_1]$ here $\cos\phi_1 = \frac{R_1}{Z_1} = \frac{R_2}{Z_2} = \frac{3}{5}$

$V_1 = 5\sin(200t)$
$V_2 = I_0 Z_2 \sin(200t)$
$V_2 = 10\sin(200t)$]

13.(a) $\frac{dN}{dt} = q - \lambda N$ $\left\{\lambda = \frac{\ln 2}{T}\right\}$

$$\Rightarrow -\int_{\frac{4qT}{\ln 2}}^{N} \frac{dN}{\lambda N - q} = \int_0^t dt$$



$$\Rightarrow \left[\ln(\lambda N - q) - \ln\left(\lambda\frac{4qT}{\ln 2} - q\right)\right] = t(-\lambda)$$

$$\Rightarrow \ln\left(\frac{\lambda N - q}{3q}\right) = -\lambda t$$

$$\Rightarrow \frac{\lambda N}{3q} = \frac{1}{3} + e^{-\lambda t} \Rightarrow N = \frac{q}{\lambda}(1 - 3e^{-\lambda t})$$

$$\Rightarrow N = \frac{qT}{\ln 2}(1 + 3e^{-\lambda t})$$

(b) At t = 2T

$$N_{2T} = \frac{qT}{\ln 2}(1 + 3e^{-2\ln 2})$$

$$= \frac{qT}{\ln 2}\left(1 + \frac{3}{\sqrt{2}}\right)$$

No. of α particle decaying
$= N_0 + q\,(2T) - N_{2T}$ [N_0 is N at t = 0]

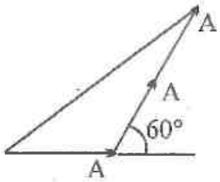
$$= qT\left[\frac{3\sqrt{2} - 3}{\sqrt{2}\ln 2} + 2\right]$$]

14.(a) $\Delta x_{12} = \frac{yd}{D} = \frac{0.7\times10^{-3}\times0.7\times10^{-3}}{2\times0.3}$

$$\Delta\phi_{12} = \frac{2\pi}{7\times10^{-7}}\times\Delta x = \frac{2\pi}{7\times10^{-7}}\times7\times10^{-7}\times\frac{0.7}{0.6} = \frac{7\pi}{3} = 2\pi + \frac{\pi}{3}$$

Similarly, $\Delta\phi_{23} = 2\pi + \frac{\pi}{3}$

$A_r^2 = (2A)^2 + A^2 + 2A^2 \times \frac{1}{2}$

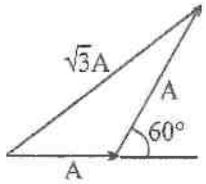


$I = 6I_0$

$I_{res} = 6I_0$

$I_0 = \frac{7\times10^{-4}}{6}$ [Intensity due to 1 slit]

(b) If only S_3 is covered



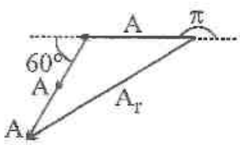
$I = 3I_0 = \frac{3}{6}I_{res}$

$I_{res} = \frac{7}{2}\times10^{-4}\ W/m^2$

(c) $\Delta x = (1.25 - 1) \times 1.4 \times 10^{-6} = \frac{0.7}{2}\times10^{-6} = \frac{7\times10^{-7}}{2} = \frac{\lambda}{2} \Rightarrow \quad \Delta\phi = \pi$

$\Rightarrow \quad \Delta\phi_{12} = \pi + \frac{\pi}{3}$

$\Delta\phi_{22} = \pi + \frac{\pi}{3}$



$A_r^2 = A^2 + 4A^2 - 2A^2 \times \frac{1}{2} = 4A^2 = 4I_0$

$I_{res} = \frac{4}{6} \times 7 \times 10^{-4} = \frac{14}{3} \times 10^{-4}\ W/m^2$]

15. (a) $v_x = 12 + 10 = 22$ m/s

$v_y = 16$ m/s

$v = \sqrt{v_x^2 + v_y^2}$

$v = \sqrt{256+484} = \sqrt{740}$ m/s

$v = \sqrt{740}$ m/s

(b) Time of flight is $= \frac{2v_y}{g} = \frac{2\times16}{10} = 3.2$ sec

$x = 3.2 \times 22 = 70.4$ m

$70.4 = 10 \times 3.2 + \frac{1}{2} \times a \times (3.2)^2$

$70.4 = 32 + 5.12\ a$

$a = 7.5\ m/s^2$

(c) $\vec{a}_{jeep} = 7.5\hat{i}$, $\vec{a}_{ball} = -10\hat{j}$

$\vec{a}_{ball/jeep} = \vec{a}_{ball} - \vec{a}_{jeep} = -10\hat{j} - 75\hat{i}$, $|\vec{a}_{ball/jeep}| = 12.5 \text{ m/s}^2$

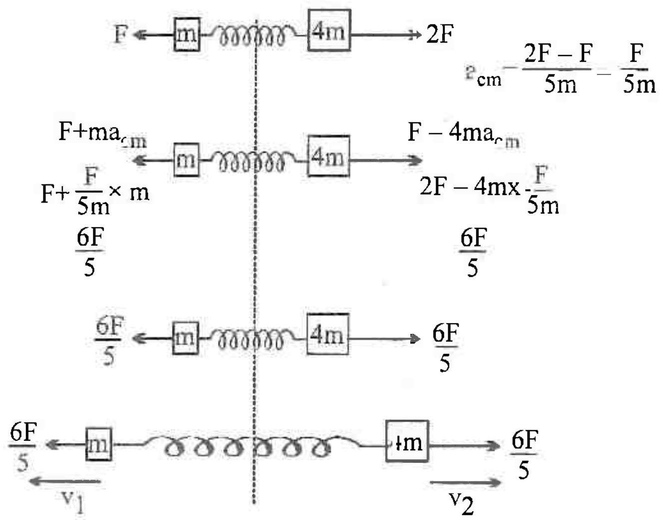
$\vec{v}_{ball/jeep} - 12\hat{i} + 16\hat{j} \Rightarrow |\vec{v}_{ball/jeep}| = 20 \text{ m/s}$

$0 = (20)^2 - 2 \times 12.5 \times s$, $s = \frac{400}{25}$

$\Rightarrow$ **s = 16 m**]

16. (a) $(2FX_1 - FX_2) - \frac{1}{2}k(X_1 - X_2)^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}4mv_2^2$

(b)



$\frac{6F}{5}Xm_1 + \frac{6F}{5}Xm_2 = \frac{1}{2}k(Xm_1 + Xm_2)^2$

$\frac{6F}{5}(Xm_1 + Xm_2) = \frac{1}{2}k(Xm_1 + Xm_2)^2$, $\quad \frac{6F}{5} = \frac{k}{2}(Xm_1 + Xm_2)$

$Xm_1 + Xm_2 = \frac{12}{5}\frac{F}{k} = \frac{12}{5} \times \frac{5mg}{k} = \frac{12mg}{k}$

maximum elongation $= \frac{12mg}{k}$

(c) $mXm_1 = 4mXm_2$, $\quad Xm_1 = 4Xm_2$

$Xm_1 + Xm_2 = \frac{12mg}{k}$, $\quad Xm_1 = 4Xm_2$

$4Xm_2 + Xm_2 = \frac{12mg}{k} \Rightarrow 5Xm_2 = \frac{12mg}{k} \Rightarrow Xm_2 = \frac{12mg}{5k}$

$Xm_1 = 4 \times \frac{12mg}{5k} = \frac{48mg}{5k}$

amplitude of mass m $= \frac{48mg}{5k}$

$$a = \sqrt{\frac{k}{\mu}} = \sqrt{\frac{k}{\frac{m \times 4m}{5m}}} = \sqrt{\frac{5k}{4m}}$$

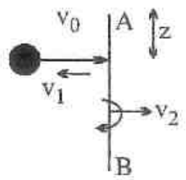
$$v_{max} \text{ of m} = \omega A = \sqrt{\frac{5k}{4m}} \times \frac{48mg}{5k} = g\sqrt{\frac{m}{5k}} \times 24 = 24g\sqrt{\frac{m}{5k}}$$

$$v_{max} = 240\sqrt{\frac{m}{5k}} \text{ m/s Ans.]}$$

17.(a)By momentum conservation,

$$5m \times v_2 - mv_1 = mv_0 \qquad ...(1)$$

By angular momentum conservation,



$$mv_0\left(\frac{l}{2} - z\right) = -mv_1\left(\frac{l}{2} - z\right) + \frac{5ml^2}{12} \times \omega \qquad ...(2)$$

By coefficient of restitution equation,

$$\frac{3}{4} = \frac{v_1 + v_2 + \omega\left(\frac{l}{2} - z\right)}{v_0 - 0} \qquad ...(3)$$

$$v_0 + v_1 = 5v_2$$

$$5v_2\left(\frac{l}{2} - z\right) = \frac{5l^2\omega}{12}$$

$$\frac{3}{4} = \frac{6v_2 - v_0 + \omega\left(\frac{l}{2} - z\right)}{v_0}; \quad \frac{7v_0}{4} = \frac{6 \times \frac{5\omega l^2}{12}}{5\left(\frac{l}{2} - z\right)} + \omega\left(\frac{l}{2} - z\right); \quad \frac{7v_0}{4} = \frac{\omega\left[\frac{l^2}{2} + \frac{l^2}{4} - lz + z^2\right]}{\frac{l}{2} - z}$$

(b) $$v_B = v_2 - \frac{\omega l}{2} = 0 \quad \Rightarrow \quad v_2 = \frac{\omega l}{2}$$

$$\frac{l^2\omega}{12\left(\frac{l}{2} - z\right)} = \frac{\omega l}{2} \quad \Rightarrow \quad \frac{l}{6} = \frac{l}{2} - z \quad \Rightarrow \quad z = \frac{l}{3}$$

(c) $$\omega = \frac{\frac{7}{4}v_0 \times \frac{l}{6}}{\left[\frac{3l^2}{4} - \frac{l^2}{3} + \frac{l^2}{9}\right]} = \frac{21v_0}{38l}$$

$$v_2 = \frac{\omega l}{2} = \frac{21v_0}{76}, \qquad v_1 = 5v_2 - v_0 = \frac{29v_0}{76}$$

$$K_f = \frac{1}{2} \times m \times \left[\frac{29v_0}{76}\right]^2 + \frac{1}{2} \times 5m \times \left[\frac{21v_0}{76}\right]^2 + \frac{1}{2} \times 5m \times \frac{l^2}{12} \times \left[\frac{21v_0}{38l}\right]^2$$

$$= \frac{1}{2}mv_0^2\left(\frac{29^2+5\times21^2+5\times7^2}{76^2}\right) = \frac{1}{2}mv_0^2\times\frac{3291}{5776}$$

$$\frac{\Delta K}{K_0} = \frac{2845}{5776}\times100 = 43\%$$]

18. (a) $C_v = m\left(\frac{\mu_1 C_{v_1}+\mu_2 C_{v_2}}{\mu_1+\mu_2}\right)$ $\mu_1 = \frac{6}{2} = 3$, $\mu_2 = \frac{8}{4} = 2$

$C_{V_1} = \frac{5R}{2}$, $C_{V_2} = \frac{3R}{2}$

$$C_v = \frac{3\times\frac{5R}{2}+2\times\frac{3R}{2}}{5} = \frac{\frac{15R}{2}+3R}{5} = \frac{21R}{10} = 2.1\text{ R}$$

$C_p = R + C_v = 2.1\text{ R} + R = 3.1\text{ R}$

$\gamma = \frac{C_p}{C_v} = \frac{3.1R}{2.1R} = \frac{31}{21}$, $\gamma = \frac{31}{21}$

(b) given :

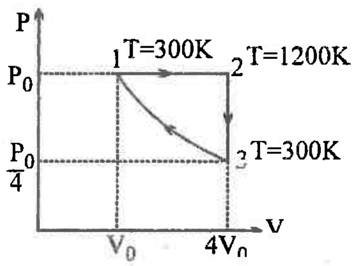
$T_1 = 300$ K $\xrightarrow{P=\text{const}}$ $T_2 = 1200$ K $\xrightarrow{V=\text{const}}$ $T_3 = 300$ K

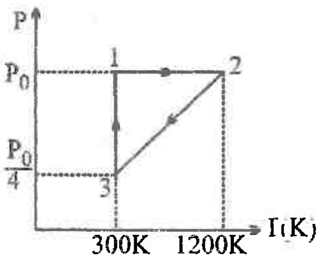
$P_1 = P_0\ 2\times10^5\text{ N/m}^2$ $P_2 = 2\times10^5\text{ N/m}^2 = P_0$ $P_3 = \frac{P_0}{4} = \frac{1}{2}\times10^5\text{ N/m}^2$

$V_1 = V_0$ $V_2 = 4V_0$ $V_3 = 4V_0$

$\xrightarrow{T=\text{const}}$

$T_1 = T_4 = 300$ K
$V_1 = V_4 = V_0$
$P_1 = P_4 = P_0 = 2\times10^5\text{ N/m}^2$





(c) Work done in entire cycle :

$W_{1\to2} = 3P_0V_0$

$W_{2\to3} = 0$

$$W_{3\to1} = nRT_3\log_e\left(\frac{V_1}{V_3}\right) = P_0V_0\log_e\left(\frac{V_0}{4V_0}\right) = -1.4\ P_0V_0$$

$W_{net} = w_{1\to2} + w_{2\to3} + w_{3\to1}$
$W_{net} = 3P_0V_0 - 1.4\ P_0V_0 = 1.6\ P_0V_0$
$W_{net} = 1.6\ P_0V_0$

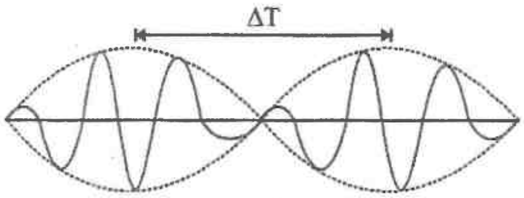
$Q_{in} = Q_{1\to2} = \Delta U_{1\to2} + W_{1\to2} = \mu C_p(T_2 - T_1)$

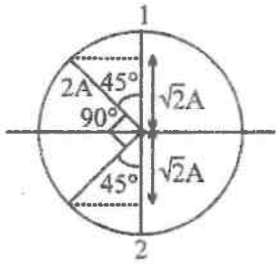
$Q_{in} = Q_{1\to2} = \mu \times 3.1\ R\ (T_2 - T_1) = 3.1\ (\mu RT_2 - \mu RT_1) = 3.1\ (P_2V_2 - P_1V_1)$
$Q_{in} = Q_{1\to2} = 3.1\ (4P_0V_0 - P_0V_0) = 3P_0V_0 \times 3.1$

$$\eta = \left(\frac{\Delta W_{net}}{Q_{in}} \times 100\right)$$

$$\eta\ \% = \frac{1.6P_0V_0}{3P_0V_0 \times 3.1} \times 100 = \frac{1.6}{3.1 \times 3} \times 100 = \frac{1.6}{9.3} \times 100; \qquad \eta\ \% = \frac{160}{9.3} = 17.2\ \%\ ]$$

19.





(a) $\Delta T = \frac{1}{1000} = 10^{-3}$ sec

(b) $I_{max} = 4A^2$
$I_0 = 2A^2$
$\Rightarrow$ when $A_{res} \le \sqrt{2}$ A then detector becomes idle

from 1 to 2, it remains idle for phase angle of 90° $\Rightarrow t_{idle} = \frac{\Delta T}{2} = 0.5 \times 10^{-3}$ s]

20.



$\mu_1 = \frac{0.06}{4.8} = 0.0125\ \text{kg/m}$ $\qquad \mu_2 = \frac{0.2}{2.56} = 0.0781\ \text{kg/m}$

$A_i = 3.5$ cm $= 3.5 \times 10^{-2}$ m

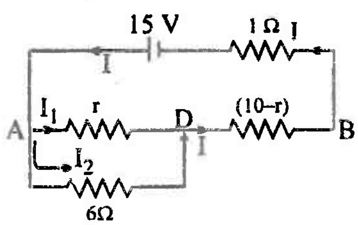
$v_1 = \sqrt{\frac{80}{0.0125}} = 80$ m/s, $\qquad v_2 = \sqrt{\frac{80}{0.0781}} \approx 32$ m/s

$$A_r = A_i\left(\frac{v_2 - v_1}{v_1 + v_2}\right) = 3.5 \times 10^{-2}\left(\frac{32 - 80}{112}\right) = -\frac{48}{112} \times 3.5 \times 10^{-2} = -\frac{3}{2} \times 10^{-2}\ \text{m}$$

$$A_t = A_i\left(\frac{2v_2}{v_1 + v_2}\right) = 3.5 \times 10^{-2}\left(\frac{64}{112}\right) = 2 \times 10^{-2}\ \text{m}$$

$$T = t_1 + t_2 = \frac{4.8}{80} + \frac{2.56}{32}\ ]$$

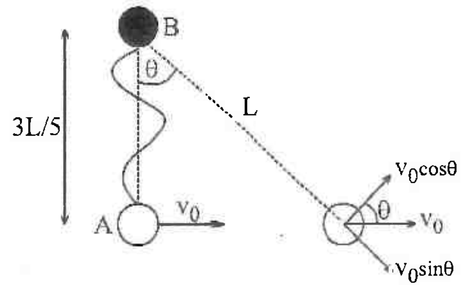
21. Given: $I_2 = 0.5$ A
$I = I_1 + I_2$
Applying Kirchoff's Law:–
$15 - 11I_1 - (11 - r) \times 0.5 = 0$ ...(1)
and $I_1r = I_2 \times 6 = 3$ ...(2)
Putting $I_1 = 3/r$ in eq. (1)
$9.5 - 11 \times (3/r) + 0.5r = 0$
$\therefore\ r^2 + 19r - 66 = 0$
$\therefore\ r = 3$
So, length AD = 3 cm]

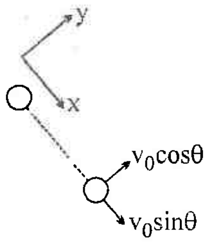


22. $v = \frac{4}{3}\pi r^3$; $\frac{dv}{dt} = 4\pi r^2 \frac{dr}{dt} = -\frac{\pi R^4}{8\eta l} \times \frac{4T}{r}$

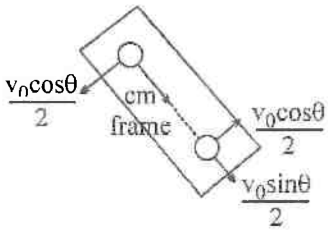
$$\Rightarrow \int_r^0 r^3 dr = -\frac{TR^4}{8\eta l}\int_0^{t_1} dt \Rightarrow \frac{TR^4}{8\eta l} t_1 = \frac{r^4}{4} \Rightarrow t_1 = \frac{2\eta l r^4}{TR^4} \text{ Ans.]}$$

23.



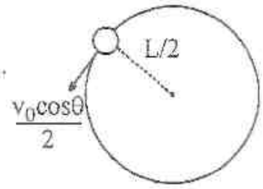


Lab frame
Fig. (A)



CM frame
Fig. (B)

In CM frame velocity of B



$$\text{Tension in string} = \frac{m\left(\frac{v_0\cos\theta}{2}\right)^2}{L/2} = \frac{2mv_0^2\cos^2\theta}{L}$$

Tangential velocity remains unchanged whereas velocity change along string for B is $\frac{v\sin\theta}{2}$

Impulse of tension $= \frac{mv\sin\theta}{2}$]

24.(a) Let wooden log moves distance x

Displacement of centre of mass along horizontal = 0

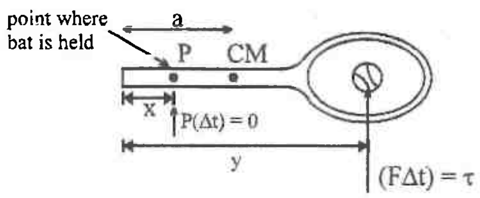
$$\therefore \quad 2m\left(\frac{L}{2} - x\right) + m\left(\frac{L}{2} - x\right) - mx = 0$$

$$\therefore \quad x = \frac{3L}{8} = 20.25 \text{ cm}$$

(b) By conservation of mechanical energy

$$\frac{1}{2}(m + m + 2m)v^2 = (2m - m)g(L\sin 60°); \qquad v = \sqrt{\frac{gL\sqrt{3}}{4}} \text{]}$$

25.

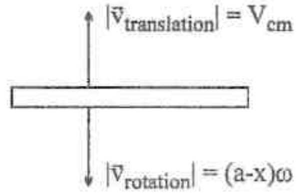


From linear momentum linear impulse equation, we get

$$F\Delta t = MV_{cm} \qquad ...(1)$$

From angular impulse angular momentum equation, we get

$$F(y-a)\Delta t = (MKL)\omega \quad ...(2)$$



$$(y-a) = \frac{(Mk^2\omega)}{MV_{cm}}$$

For point to be stationary

$$V_{cm} = (a-x)\omega$$

$$\frac{V_{cm}}{\omega} = (a-x) = \frac{k^2}{(y-a)} \qquad \text{or} \qquad x = a - \frac{k^2}{(y-a)}$$]

26. $mg + 1.36 = \rho_1 vg$

$mg + 0.82 = \rho_2\, vg$

$mg + 1 = \rho\, vg$

$$\rho = \frac{\rho_1 v_1 + \rho_2 v_2}{v_1 + v_2}$$

solving we get $\frac{v_1}{v_2} = \frac{1}{2}$ Ans.]

27. If system is balance then

$$T_1 \times \frac{d_1}{2} = T_2 \times \frac{d_2}{2},\ T_1 d_1 = T_2\, d_2 \qquad .....(i)$$

$$2T_1 = Mg \sin 30° = \frac{Mg}{2},\ T_1 = \frac{Mg}{4} \quad ....(ii)$$

$T_2 = 10 \times 10 = 100$ N , $T_2 = 100$ N .....(iii)

from (i) $d_2 = 3d_1$, $T_1 \times d_1 = T_2 \times 3d_1$, $T_1 = 300$ N

from (ii) $300 = \frac{M \times g}{4}$, M = 120 kg

M = 120 kg]

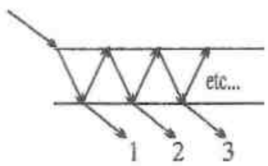
28. Ray 1 carries $(1-k)^2$ of the beam's energy;

Ray 2 carries $k^2(1-k)^2$ of the beam's energy;

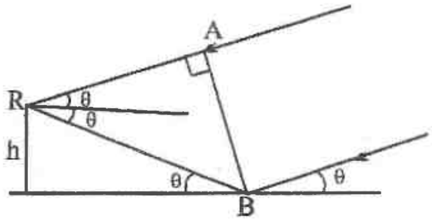
Ray 3 carries $k^4(1-k)^2$ of the beam's energy; etc.

The total fraction of transmitted energy is

$$(1-k)^2 + k^2(1-k)^2 + k^4(1-k)^2 + \ldots$$
$$= (1-k)^2(1 + k^2 + k^4 + \ldots) = (1-k)^2/(1-k^2)$$
$$= (1-k)/(1+k) = 7/13 = 53.8\%$$]



29. $RB = \dfrac{h}{\sin\theta}$



$RA = RB \cos 2\theta$

$= \dfrac{h}{\sin\theta}(\cos 2\theta)$

path difference $\Delta p = RB - RA$

$\Delta p = \dfrac{h}{\sin\theta}(1 - \cos 2\theta) = 2h \sin\theta = \lambda$

$2 \sin\theta = \dfrac{\lambda}{h} \Rightarrow 3 \times \dfrac{\pi}{180} = \dfrac{2\lambda}{2(4m)}$

$\lambda = 4 \times \dfrac{\pi}{30} m = 0.42$ m]

30. $\dfrac{v_1^2 - v_2^2}{2g} = \dfrac{(35-20)}{100}$ (in meter)

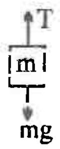
Also, $v_1(1) = v_2(2)$ (by equation of continunity)

$\therefore \dfrac{3v_2^2}{2g} = \dfrac{15}{100}$

$\therefore v_2 = 1$ m/s

$\therefore$ mass flow rate $= \sigma \times v_2 \times A_2 = 1000 \times 1 \times 2 \times 10^{-4}$
$= 0.2$ kg /sec

Now, $\dfrac{v_2^2 - v_3^2}{2g} = \dfrac{37.5-35}{100}$; $1 - v_3^2 = \dfrac{2.5}{100} \times 20$; $v_3 = \dfrac{1}{\sqrt{2}}$ m/s]

31. 

suppose v is the constant velocity then $\omega = \dfrac{v}{r}$

$\vec{\tau} = IAB$

$I = \dfrac{e}{R} = \dfrac{1}{R} \times \dfrac{1}{2} Br^2 \times \dfrac{v}{r} = \dfrac{Brv}{2R}$

$\tau = IAB = \dfrac{Brv}{2R} \times \pi r^2 B \quad \Rightarrow \quad \tau = \dfrac{1}{2}\dfrac{B^2 \pi r^3 v}{R}$

current I: when v = 3 m/sec

$I = \dfrac{e}{R} = \dfrac{1}{2}\dfrac{Brv}{R} = \dfrac{1}{2} \times \dfrac{0.5 \times 0.2 \times 3}{0.15} = 1A$ Ans

for highest velocity net torque on the ring should be zero

$\tau = mgr = \dfrac{1}{2}\dfrac{B^2 \pi r^3 v}{R}$; $v = \dfrac{2mgR}{B^2 \pi r^2} = \dfrac{2 \times 20 \times 10^{-3} \times 10 \times 0.15}{0.25 \times \pi \times 4 \times 10^{-2}} = \dfrac{3}{5 \times 3.14} = 0.2$ m/sec Ans.

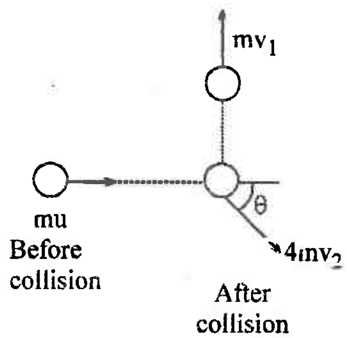
and $\tau = mgr = 20 \times 10^{-3} \times 10 \times 0.2 = 4 \times 10^{-2}$ N-m Ans.]

32.(a) $\frac{1}{N}\frac{dN}{dv} = Cv^2$; $\frac{\int_0^N dN}{N} = \int_0^{v_0} Cv^2 dv \Rightarrow 1 = \frac{Cv_0^3}{3} \Rightarrow C = \frac{3}{v_0^3}$

(b) $v_{av} = \frac{\int_0^{v_0} v dN}{N} = \int_0^{v_0} Cv^3 dv = \frac{3}{v_0^3}\left[\frac{v_0^4}{4}\right] = 0.75v_0$

(c) $v_{rms} = \sqrt{\frac{\int_0^{v_0} v^2 dN}{N}} = \sqrt{\int_0^{v_0} Cv^4 dv} = \sqrt{\frac{3}{v_0^3} \times \frac{v_0^5}{5}} = v_0\sqrt{\frac{3}{5}} = 0.775\ v_0$]

33. $mu = 4mv_2 \cos\theta$ ...(1)
$mv_1 = 4mv_2 \sin\theta$ ...(2)
From eq. (1) & (2)
$u^2 + v_1^2 = 16v_2^2$ ...(3)



$E_1 = -(13.6\ eV)z^2 = -54.4\ eV$

$E_2 = -\frac{(13.6z^2)}{4} = -13.6\ eV$

$E_3 = -\frac{(13.6z^2)}{9} = -6.4\ eV$

$E_4 = -\frac{(13.6z^2)}{16} = -3.4\ eV$

$\Delta E_1 = E_2 - E_1 = 40.8\ eV$
$\Delta E_2 = E_3 - E_1 = 48\ eV$
$\Delta E_3 = E_4 - E_1 = 51\ eV$
$\Delta E_4 = E_3 - E_2 = 7.2\ eV$

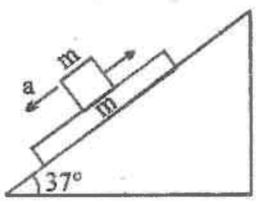
$$65eV = \frac{1}{2}mv_1^2 + \frac{1}{2}(4m)v_2^2 + \Delta E = \frac{1}{2}mv_1^2 + \frac{1}{2}(4m)\left[\frac{u^2+v_1^2}{16}\right] + \Delta E \quad ...(4)$$

$$65eV = \frac{1}{2}mv_1^2 + \frac{1}{8}mv_1^2 + \frac{65eV}{4} + \Delta E$$

On substituting $\Delta E_3 = 51$ eV

mv_1^2 comes out to be negative, which implies that, electron transition upto n = 3 is possible. In subsequent de-excitation the possible energies are
$\Delta E_1 = 40.8$ eV [n = 2 to n = 1]
$\Delta E_2 = 48$ eV [n = 3 to n = 1]
$\Delta E_4 = 7.2$ eV [n = 3 to n = 2]]

34. Net external force = $M_{system}a_{cm}$



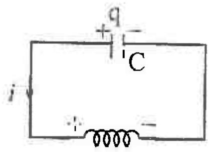
$\therefore \quad 2mg \sin\theta = 2m\left(\frac{ma + 0}{2m}\right)$

$\Rightarrow \quad a = 2g \sin\theta$

$$a = \frac{m+m}{m} g \sin\theta$$

Also $v^2 - \frac{v^2}{4} = 2ad$; $d = \frac{3v^2}{8a}$; solving we get d = 2 m/s Ans.]

35. Let at any instant t charge is q



$\therefore \quad i = -\frac{dq}{dt}$ [charge decreasing]

$\therefore \quad \frac{di}{dt} = -\frac{d^2q}{dt^2}$

$\frac{q}{C} = L\frac{di}{dt} \Rightarrow \frac{q}{C} = -L\frac{d^2q}{dt^2}$; $\therefore \frac{d^2q}{dt^2} = -\frac{q}{LC}$

$\therefore \quad q = q_0 \sin\left(\frac{1}{\sqrt{LC}}t + \phi\right)$

at t = 0, $q = q_0 \Rightarrow \quad \phi = \pi/2$

$\therefore \quad q = q_0 \cos\left(\frac{1}{\sqrt{LC}}t\right)$

Now, when energy becomes half then

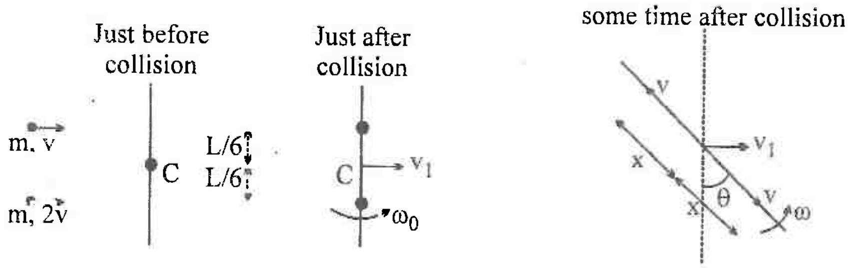
$\frac{1}{2}\frac{q^2}{C} = \frac{1}{4}\frac{q_0^2}{C} \Rightarrow q = \frac{q_0}{\sqrt{2}}$

Let it happens at $t = t_0$

$\therefore \quad \frac{q_0}{\sqrt{2}} = q_0\cos\left(\frac{1}{\sqrt{LC}}t_0\right)$; $\therefore \frac{1}{\sqrt{LC}}t_0 = \pi/4$

$\therefore \quad t_0 = \frac{\pi}{4}\sqrt{LC} = 5\pi \times 10^{-5}$ sec]

36.



Applying conservation of angular momentum about CM of the system which is CM of the rod just after collision

$$m2v\left(\frac{L}{6}\right) - mv\left(\frac{L}{6}\right) = \left[\frac{2mL^2}{12} + m\left(\frac{L}{6}\right)^2 + m\left(\frac{L}{6}\right)^2\right]\omega_0$$

$$\omega_0 = \frac{3v}{4L}$$

Applying conservation of angular momentum about CM of the system just after collision and at the time when insects are at distance x from centre

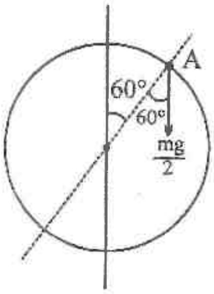
$$\left(\frac{2mL^2}{12}+mx^2+mx^2\right)\omega = \frac{2mL^2}{9}\omega_0 \quad \Rightarrow \quad \omega = \frac{2\omega_0 L^2}{9\left[\frac{L^2}{6}+2x^2\right]}$$

$$d\theta = \frac{2L^2\omega_0 dt}{9\left[\frac{L^2}{6}+2x^2\right]}; \quad \int_0^{\theta_1} d\theta = \frac{L^2\omega_0}{9v}\int_{L/6}^{L/2}\frac{dx}{\left(\frac{L^2}{12}+x^2\right)};$$

$$\Rightarrow \quad \theta_1 = \frac{\omega_0 L\sqrt{12}}{9v}\left[\tan^{-1}\sqrt{3}-\tan^{-1}\frac{1}{\sqrt{3}}\right] = \frac{\omega_0 L\pi}{9\sqrt{3}v} - \frac{\pi}{12\sqrt{3}} \text{ radian Ans.]}$$

37. (a) $\left(\frac{Mg}{2}\right)(R\sin 60°) = \tau = I\alpha$

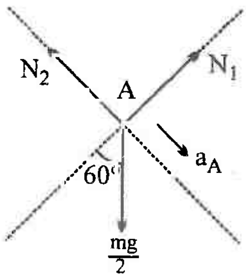
$$\therefore \alpha = \frac{\left(\frac{M}{2}g\right)(R\sin 60°)}{\left[\frac{1}{2}mR^2+\left(\frac{m}{2}\right)R^2\right]}$$



$$\alpha = \frac{g\sqrt{3}}{4R}$$

$$\therefore a_A = \left(\frac{g\sqrt{3}}{4R}\right)R = \frac{g\sqrt{3}}{4}$$

(b) $N_1 = \frac{mg}{2}\cos 60° = \frac{mg}{4}$

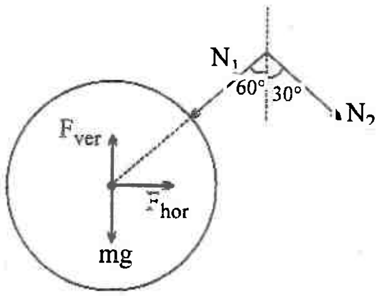


and $\frac{mg}{2}\sin 60° - N_2 = \frac{m}{2}a_A$

$$N_2 = \frac{mg\sqrt{3}}{8}$$

$$F_{ver} = mg + N_1\cos 60° + N_2\cos 30°$$

$$= \frac{21}{16}mg$$



$$F_{hor} = N_1\sin 60° - N_2\sin 30°$$

$$= \frac{mg\sqrt{3}}{16} \quad]$$

38. Time taken by A to reach to B $t_1 = 1/4$
now velocity of B will be 4 m/s

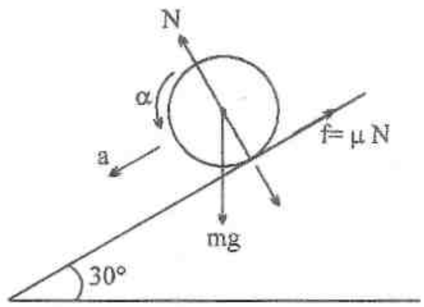
time taken by B to oscillate $= \pi\sqrt{\frac{m}{k}}$

$$t_2 = \pi\sqrt{\frac{1}{16\pi^2}} = \frac{\pi}{4\pi} = \frac{1}{4}$$

time taken by A to go back to left wall is $= 1/4 - t_3$

total time period of this oscillatory system $= t_1 + t_2 + t_3 = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} \Rightarrow T = \frac{3}{4}$ sec]

39. $\because \; m < \frac{\tan\theta}{1+(R^2/K^2)}$, rolling will not occus



$$a = \frac{mg(\sin\theta - \mu\cos\theta)}{m}$$

Also $\alpha = \frac{\mu mgR\cos\theta}{mR^2} = \frac{\mu g\cos\theta}{R}$

If t is the time to complete one revolution

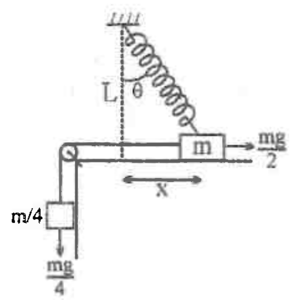
$$\frac{1}{2}\alpha t^2 = 2p$$

Distance travelled by centre

$$s = \frac{1}{2}at^2 = \frac{2\pi a}{\alpha} = \frac{2\pi R(\sin\theta - \mu\cos\theta)}{\mu\cos\theta} = \frac{2\pi(5-\sqrt{3})}{\sqrt{3}}$$]

40.(a) Initial acceleration $= \frac{\frac{mg}{2} - \frac{mg}{4}}{\frac{5m}{4}} = g/5$

(b) At the instant when spring makes an angle θ with vertical



$x = L\tan\theta$

$$\frac{mg}{2} \times L\tan\theta - \frac{mg}{4} \times L\tan\theta + W_s = \frac{1}{2}\left(m + \frac{m}{4}\right)v^2$$

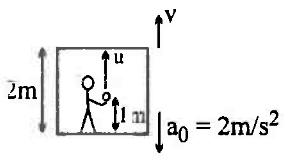
W_s = work done by spring force = – change in spring energy

$$\therefore \quad \frac{mgL\tan\theta}{2} - \frac{mgL\tan\theta}{4} - \frac{1}{2}k[L\sec\theta - L]^2 = \frac{5}{8}mv^2$$

(c) For v = 0 $x = \sqrt{3}L$ $\Rightarrow$ $\theta = 60°$

$$\therefore \quad \frac{\sqrt{3}mgL}{4} = \frac{1}{2}kL^2$$

$$\therefore \quad k = \frac{\sqrt{3}mg}{2L} \quad]$$

41. 

w.r.t. to lift

acceleration of coin, $a' = g - a_0 = 8\ m/s^2$

$u_{rel} = 3$ m/s

maximum height, $H' = \frac{u_{rel}^2}{2a'} = 0.56\ m < 1\ m$

so, it cannot touch the roof of lift.

Now, let t_0 is time taken to reach the floor

$$\therefore \quad -1 = 3t_0 - \frac{1}{2}(8)t_0^2$$

On solving, $t_0 = 1$ sec

w.r.t. ground

Initial velocity, $v_0 = 8$ m/s

Maximum height, $H = \frac{v_0^2}{2g} = 3.2$ m

Time taken for upward motion, $t_1 = v_0/g = 0.8$ s

Time taken for downward motion, $t_2 = 1 - 0.8$ sec $= 0.2$

Distance travelled during downward motion = $(1/2)g \times (0.2)^2 = 0.2$ m

Total distance travelled = 3.2 + 0.2 = 3.4 m

Displacement till that time = $8(1) - (1/2)g \times (1)^2 = 3$ m]

42. Point source – spherical wavefront $\Rightarrow$ $I \propto \frac{1}{d^2}$ $\Rightarrow$ $I_1 = 4I$

$$L = 10 \log_{10}\frac{I}{I_0} = 30 \quad .....(1)$$

$$L_1 = 10 \log_{10}\frac{4I}{I_0} = 10[\log_{10}4] + L = 20 \log_{10}2 + 30 \approx 36 \text{ dB}$$

sound will be inaudible if

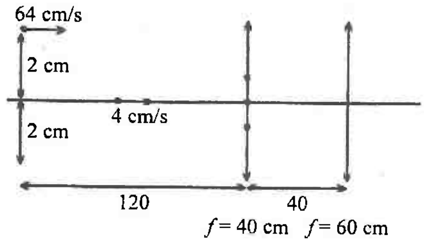
$I_2 = I_0$

from (1) $I = 1000I_0$

$$\frac{I}{I_2} = 1000 = \frac{d_2^2}{d(20)^2}$$

$d_2 = 200\sqrt{10}$ m]

43. $m = \frac{f}{f+u} - \frac{40}{40+(-30)} = 4$



$m = v/u$

$v = -120$ cm

$v_{I_x} = m^2 v_{O_x}$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$v_{I_x} = 16 \times 4$

$\frac{1}{v} - \frac{1}{-30} = \frac{1}{+40} = \frac{1}{40} - \frac{1}{30} \Rightarrow v = -120$

$= 64$ cm/s

Generaly equation for y-component of velocity of image

$\frac{y_I}{y_0} - \frac{f}{f+x_0}$; $v_{I_y} = \frac{d}{dt}\left[y_0\left(\frac{f}{f+x_0}\right)\right]$

$= \frac{dy_0}{dt} \times m - \frac{y_0 f}{(f+x_0)^2} \times \frac{dx_0}{dt} = mv_{y_0} - \frac{v_{x_0} \times y_0 f}{(f+x_0)^2} x$ ...(1)

Applying equation (1) for first lens with $v_{y_0} = 0$ and then applying for second lens with

$v_{y_0} = -16/5$ cm

$v_{o_y} = -\frac{y_0 f}{(f+x_0)^2}\frac{dx_o}{2dt} = -(16/5)$ cm/s

Now substitute v_{o_y} and $m = \frac{60}{60+(-160)} = -\frac{3}{5}$ in eq. (1), to get

$= -\frac{3}{5} \times \left(\frac{\cdot 16}{5}\right) - \frac{64 \times 2 \times 60}{(60-160)^2} = 144/125$

Therefore, relative velocity $= 2 \times \frac{144}{125}$]

44.(a) To determine the specific heat capacity of unknown solid,

we use $s_{solid} = \frac{m_1 s_1 + m_2 s_2}{m_1}\left(\frac{\theta_{ss} - \theta_2}{\theta_1 - \theta_{ss}}\right)$ and get $s_{solid} = 1/2$ cal/g/°C

$\left(\frac{ds}{s}\right)_{max} = 2\Delta\theta\left(\frac{1}{\theta_{ss}-\theta_2} + \frac{1}{\theta_1 - \theta_{ss}}\right) = 2\ (0.1°C)\left(\frac{1}{40.0-20.0} + \frac{1}{80.0-40.0}\right) = 1\%$]

(b) $s_1 = \left(\frac{m_2 s_2 + m_3 s_3}{m_1}\right)\left(\frac{\theta - \theta_2}{\theta_1 - \theta}\right)$

substituting value, we get $s_1 = 0.5$ cal/g°C for finding error in s_1

$\alpha s_1 = \left(\frac{m_2 s_2 + m_3 s_3}{m_1}\right)\left[\frac{(\theta_1 - \theta)(d\theta - d\theta_2)}{(\theta_1 - \theta)^2} - (\theta - \theta_2)(d\theta_1 - d\theta)\right]$

$$\frac{ds_1}{s_1}=\frac{(d\theta-d\theta_2)(\theta_1-\theta)-(\theta-\theta_2)(d\theta_1-d\theta)}{(\theta_1-\theta)(\theta-\theta_2)}=\frac{(\theta_1-\theta)+(\theta-\theta_2)d\theta-d\theta_2(\theta_1-\theta)-d\theta_1(\theta-\theta_2)}{(\theta_1-\theta)(\theta-\theta_2)}$$

$$\frac{\Delta s_1}{s_1}=\frac{(\theta_1-\theta_2)\Delta\theta+(\theta_1-\theta)\Delta\theta_2+(\theta-\theta_2)\Delta\theta_1}{(\theta_1-\theta)(\theta-\theta_2)};\qquad \frac{\Delta s_1}{s_1}=\frac{\Delta\theta[2(\theta_1-\theta_2)]}{(\theta_1-\theta)(\theta-\theta_2)}$$

Δs_1 is minimum when $(\theta_1-\theta)(\theta-\theta_2)$ is maximum.

This happens when $\theta=\frac{\theta_1+\theta_2}{2}$

$\Rightarrow$ steady state temperature should be $\frac{20+80}{2}$ = 50°C Ans.]

45. 1 cm, 1 cm

46. (a) 0.2 cm; (b) –0.1 cm ; (c) 12 cm

[Sol.(c) u = 30.2 – 0.2 (excess reading)
= 30.2 cm
v = 19.9 – (–0.1) (excess reading)
= 20.0 cm.

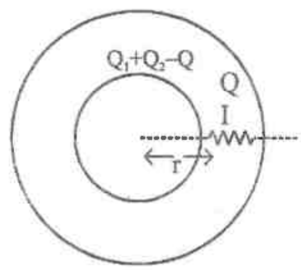
$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}\Rightarrow f=12.0$ cm]

47. t = t Let charge on outer shell is Q $\Rightarrow$ charge on innershell = Q_1+Q_2-Q

$\Rightarrow$ Leakage current $I=\frac{dQ}{dt}$

at distance r from centre

$J=\sigma E$



$$\frac{I}{4\pi r^2}=s\left(\frac{Q_1+Q_2-Q}{4\pi\epsilon_0 Kr^2}\right)$$

$$I=\frac{\sigma(Q_1+Q_2-Q)}{\epsilon_0 K}$$

$$\frac{dQ}{dt}=\frac{\sigma(Q_1+Q_2-Q)}{\epsilon_0 K}$$

$$\int_{Q=Q_2}^{Q=Q}\frac{dQ}{Q_1+Q_2-Q}=\int_{t=0}^{t=t}\frac{\sigma}{\epsilon_0 k}dt$$

$$\Rightarrow\frac{-\ell n\ Q_1+Q_2-Q}{Q_1}=\frac{\sigma}{\epsilon_0 k}\Rightarrow\frac{Q_1+Q_2-Q}{Q_1}=e^{-\frac{\sigma t}{\epsilon_0 k}}\qquad\Rightarrow Q=Q_2+Q_1\left(1-e^{-\frac{\sigma t}{\epsilon_0 k}}\right)]$$

48. The expression for the electric field can be obtained as

$E=k(1+\cos\Omega t)\cos\omega t$

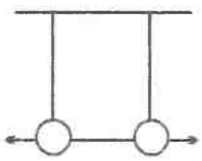
$-k\cos\omega t+\frac{1}{2}k\cos(\omega-\Omega)t+\frac{1}{2}k\cos(\omega+\Omega)t,$

When the product of the two cosines is expanded using a standard trigonometric identity. These three terms corresponds to photons of energies $h\omega$, $h(\omega-\Omega)$. The latter exceeds the ionization energy by 0.7 eV. That difference equals the ejected electron energy.]

49. One can use the formula for the capacitance of a parallel-plate capacitor:
$C = \varepsilon_0 A/d$.
According to the definition of capacitance, the charge on one plate is $Q = CE$, where E is the emf (and the voltage across the capacitor).
Also, the current is given by
$I(t) = dQ / dt$
$I(t) = E(dC / dt)$
$I(t) = E(dC/dd)(dd/dt)$
One can see that $(dC/dd) = (-\varepsilon_0 A/d^2)$
Since $d \approx d_0$, $(dC/dd) \approx (-\varepsilon_0 A/d_0^2)$
Also, $(dd/dt) = (a\omega \sin \omega t)$
$I(t) = (E\varepsilon_0 A/d_0^2)(a\omega \sin \omega t)$
The amplitude of the current is then
$I = E\varepsilon_0 A\, a\omega/d_0^2$, so

$$a = \frac{Id_0^2}{EA\omega\varepsilon_0}$$ Ans.]

50. The fact that the pendula hang vertically at equilibrium implies that the rubber band tension is zero at that moment. If the bobs are each displaced a distance x, then the rubber band is stretched by 2x, resulting in a tension of 2kx. Gravity and the string tension act together to produce an additional restoring force of mgx/L on each bob. The total restoring force on each bob is then $-(2k + mg/L)x$ when the bobs are moved outward from their equilibrium positions and $-(mg/L)x$ when they are moved inward.



In general, the period of a simple harmonic motion is $T = 2\pi/\omega$. Then, for the first (outward) half-cycle this becomes $P_1 = 2\pi[m/(2k + mg/L)]^{1/2} = 2\pi(2k/m + g/L)^{-1/2}$ and for the second (inward) half-cycle it is $P_2 = 2\pi[m/(mg/L)]^{1/2} = 2\pi(g/L)^{-1/2}$. To find the period of the motion we add the two half-periods: $T = (P_1 + P_2)/2 = \pi[(2k/m + g/L)^{-1/2} + (g/L)^{-1/2}]$

51. In the center of mass (c.m.) reference frame, all the kinetic energy is conserved to electrostatic potential energy at the final instant. The center of mass velocity is 3v/5 (assuming the alpha particle is travelling in the positive direction), so the incoming alpha velocity is 2v/5 and the incoming proton velocity is $-8v/5$. Therefore, the total kinetic energy in the c.m. reference frame is $8mv^2/5$. At the final instant, the electrostatic potential energy of the system is $e^2/2\pi\varepsilon_0 r$. Solving for r gives $r = 5e^2/16\pi\varepsilon_0 mv^2$.]

52. Since the bullet's loss of speed ($\Delta v = v - u$) is small compared to u, we can assume that its deceleration is fairly uniform while passing through the block, so the upward force exerted by the bullet on the block is also fairly steady. The time that it spends passing through the block can be found:

$$\Delta t = d/v_{av} = 2d/(v + u)$$

The upward impulse exerted on the block is equal to the bullet's loss in momentum:

$$F\Delta t = m(v - u)$$

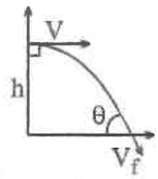
so, $F = m(v - u)/\Delta t$. Since the block does not quite lose contact with its support, we set that force equal to the weight of the block : $Mg = m\Delta v/\Delta t$.

Solving for M and replacing the Δv and Δt with the expressions above, we find that the minimum block mass is $M = m(v^2 - u^2)/(2gd) = 6.0$ kg]

53. Minimum θ implies minimum V_{iy} and maximum V_{fx}.

In order to have the aforementioned situation, the rock has to be launched horizontally.

Then: $V_{fy} = V_y^2 + 2gh$ $(g > 0, V_y = 0)$



$V_{fx} = V$

$\tan\theta = V_{fy}/V_{fx}$, so

$V_{fy} = V\tan\theta$

$V_{iy}^2 = V^2\tan^2\theta$

Also:

$V_{iy}^2 = 2gh$ and $h = v\tan^2\theta/(2g)$]

54. The rate at which heat is transferred by a single rod is given by the expression:

$$P = \frac{Q}{T} = kA\frac{t_h - t_c}{L} = C(t_h - t_c)$$

in which A is the area, L is the length and k is the thermal conductivity, the only factor different in the two experiments. Since $A(t_h - t_c)/L$ is a constant, let C denotes it. When you put two rods in series you would have:

$$P = \frac{A(t_h - t_c)}{\frac{L_1}{k_1} + \frac{L_2}{k_2}}$$

For our case, $L_1 = L_2 = L$. So we have:

$$P = \frac{A(t_h - t_c)}{L}\left(\frac{1}{1/k_1 + 1/k_2}\right) = C\left(\frac{k_1k_2}{k_1 + k_2}\right)$$

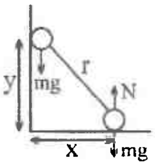
$$\Rightarrow \quad \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$

We have $T_1 = Q/P_1$, $T_2 = Q/P_2$ and $T = Q/P$

$$T = \frac{Q}{P} = \frac{Q}{P_1} + \frac{Q}{P_2} = T_1 + T_2 = 80 \text{ min.}]$$

55. First, one can connect the voltage source, the unknown resistor r and the ammeter in series. The voltmeter should be connected in parallel with the ammeter. The ratio of the readings, (V/I) equals the resistance of the ammeter. Then the voltmeter should be reconnected in parallel with both the ammeter and the unknown resistor. The ratio of the new readings (V'/I') now equals the total resistance of the ammeter and the unknown resistor. The unknown resistance r is, therefore, given by r = (V'/I') – (V/I).]

56. Since the normal force on the top mass is zero and the horizontal acceleration of the top mass is zero at the instant it loses contact with the wall, the tension in the rod at that moment must be zero. Thus, free-body diagrams for the two masses are as sketched below.



Therefore, the top mass has downward velocity v = –dy/dt and acceleration g = $-d^2y/dt^2$, while the bottom mass has rightward velocity u = dx/dt and zero acceleration.

But y = $\sqrt{r^2 - x^2}$ since the length of the rod is fixd, and thus

$$v = -\,dy/dt = \frac{x}{\sqrt{r^2 - x^2}}\frac{dx}{dt} = \frac{xu}{y}$$

and
$$g = -\,d^2y/dt^2 = \frac{u\,dx}{y\,dt} - \frac{xu\,dy}{y^2\,dt} = \frac{u^2}{y} + \frac{xuv}{y^2} = \frac{y^2u^2}{y^3} + \frac{x^2u^2}{y^3} = \frac{r^2u^2}{y^3}$$

Finally, from conservation of mechanical energy,

$$mg(r - y) = \frac{1}{2}m(u^2 + v^2)$$

$$\Rightarrow \quad 2g(r - y) = u^2\left(1 + \frac{x^2}{y^2}\right) = \frac{u^2r^2}{y^2} = gy$$

so that

$$y = \frac{2}{3}r \qquad \Rightarrow \qquad u = \sqrt{\frac{8gr}{27}}\ ]$$

57. The heating element will consist of several segments of wire connected in parallel. For maximum heating power, each segment must carry the greatest possible current, which is 2 A. Therefore, the resistance of each segment must be 110 V/2 A = 55 Ω. Since, 536/55 = 9.74, we can only use nine segments. Each segment will have length = (55/536) L, where L = the original length of the wire. (The tenth piece will be too short and must be discarded) The heating power will then be 9 × 110 V × 2.0 A = 1980 W]

58. Let the mass have descended a distance y and be at speed v. The changing magnetic flux through the circuit loop leads to a Faraday emf BLv. This emf is related to the charge on the capacitor as

$$q = CBLv$$

Differentiating with respect to time gives the current in the loop

$$I = CBL\frac{dv}{dt}$$

The magnetic force on the current carrying bar (upward if the bar is descending) is given by

$$F_{mag} = BIL = CB^2L^2\frac{dv}{dt}$$

The net downward force on the bar and Newton's second law of motion gives

$$mg - ky - CB^2L^2\frac{dv}{dt} = m\frac{d^2y}{dt^2}$$

Transforming to the new variable $u = y - \frac{mg}{k}$ allows the equation of motion to be written in the form

$$\frac{d^2u}{dt^2} + \frac{k}{m + CB^2L^2}u = 0$$

This is the familiar simple harmonic motion equation with angular frequency $\omega = \sqrt{\frac{k}{m + CB^2L^2}}$ and so the period of oscillation is

$$T = 2\pi\sqrt{\frac{m + CB^2L^2}{k}}$$]

59. That charge is finite because the second inductor shorts out the battery so that the final voltage between the top and bottom of the diagram will be zero. It will take some time to reach that condition because the current in L_2 will approach its asymptotic value gradually. Let "I" be the current through L_1 and let "i" be the current through L_2. (Both currents are functions of time.) The voltages across the three vertical parts of the network must be equal:

$V = RI + L_1 dI/dt$ ...(1)

$V = E - r(I + i)$ ...(2)

$V = L_2\, di/dt$ ...(3)

Combining eqs. (1) and (3),

$RI + L_1\, dI/dt = L_2\, di/dt$ ...(4)

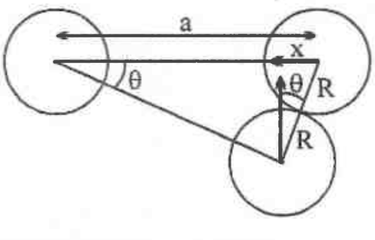
It seems likely that V will decay exponentially. ($V = V_0 e^{-kt}$) so the terms on the right sides of eqs. (1) and (3) must decay in similar fashion:

$I = I_0 e^{-kt}$, so $dI/dt = -kI_0 e^{-kt}$ and $i = i_f(1 - e^{-kt})$

so $di/dt = ki_f e^{-kt}$

By plugging those expressions into eq. (4) and cancelling the exponentials we find that $RI_0 - kI_0L_1 = ki_fL_2$. Solving for the unknown constant, $k = RI_0/[I_0L_1 + i_fL_2] = R/[L_1 + (i_f/I_0)L_2]$.
But $I_0 = E/(R + r)$ and $i_f = E/r$, so $i_f/I_0 = (R + r)/r]$.
Therefore, $k = R/[L_1 + L_2(R + r)/r]$
To check the solution it has to be seen if it is consistent with eq. (2):
$V_0\, e^{-kt} = E - r(I + i) = E - r[I_0e^{-kt} + i_f(1 - e^{-kt})] = (E - r\, i_f) + r(i_f - I_0)e^{-kt}$.
$(E - ri_f) = 0$, so factor out the exponential:
$V_0 = r\,(i_f - I_0) = r[E/r - E/(R + r)] = E[1 - r/(R + r)] = E[R + r - r]/(R + r) = ER/(R + r)$.
To find the total charge that passes through resistor R, integrate I with respect to time, from t = 0 to ∞

$Q = \int I\, dt = I_0 \int e^{-kt}\, dt = I_0/k = [E/(R + r)][L_1 + L_2(R + r)/r]/R = (E/R)[L_1/(R + r) + L_2 r]$]

60. 

$\sin\theta = 2R/a = x/(2R)$

$\therefore\ x = 4R^2/a = \frac{4 \times 0.1 \times 0.1}{1} = 0.04$ m = 4 cm]

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (P, Q, R, S)

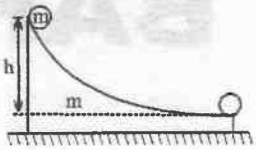
ROTATIONAL DYNAMICS

CONTENTS

EXERCISE–I

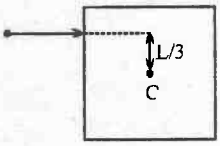
Q.1 A particle of mass m is projected with a velocity u at an angle of θ with horizontal. Find the intial angular momentum of the particle about the highest point of its projectory.

Q.2 A hollow sphere is released from the top of a movable wedge as shown in the figure. There is no friction between the wedge and the ground. There is sufficient friction between sphere and wedge to provide pure rolling of sphere. Find the velocity of centre of sphere w.r.t. ground just before it leaves the wedge horizontally.(Assume masses of the wedge and sphere are equal & h >> R the radius of sphere)



Q.3 A bit of mud stuck to a bicycle's front wheel of radius r detaches and is flung horizontally forward when it is at the top of the wheel. The bicycle is moving forward at a speed v and it is rolling without slipping. Find the horizontal distance travelled by the mud after detaching from the wheel.

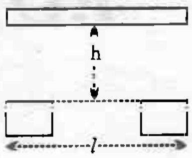
Q.4 In the figure shown, the ball of mass m (having velocity v_0) hits the surface of a stationary square plate of mass m and side L, with center pivoted at C on a smooth horizontal table .Due to the collision, the ball stops. Find the angular velocity of the plate after collision.



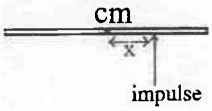
Q.5 A wheel, of radius 1 m, is rolling purely on a flat, horizontal surface. It's centre is moving with a constant horizontal acceleration = 3 m/s^2. At a moment when the centre of the wheel has a velocity 3 m/s, then find the acceleration of a point 1/3 m vertically above the centre of the wheel.

Q.6 A force of constant magnitude F starts acting on a uniform rod AB in gravity free space at the end A of the rod. The force always remains perpendicular to the rod, even as it moves. The mass of the rod is M and its length L. Then, find the value of the dot product $\vec{F}.\vec{a}_A$ at any later time(where $\vec{a}_A$ is acceleration of point A.)

Q.8 A uniform horizontal rod of length l falls vertically from height h on two identical blocks placed symmertrically below the rod as shown in figure. The coefficients of restitution are e_1 and e_2. Find the maximum height through which the centre of mass of the rod will rise after bouncing off the blocks.

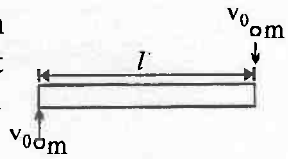


Q.9 A uniform rod of length l is given an impulse at right angles to its length as shown. Find the distance of instantaneous centre of rotation from the centre of the rod.

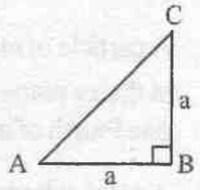


Q.10 A small ring of mass m is threaded on a horizontal smooth rod which is rotating about its end with constant angular velocity ω. The ring is initially located at the axis of rotation. When the distance of the ring from the axis becomes r, then find the power required to rotate the system with same angular velocity.

Q.11 On a smooth table two particles of mass m each, travelling with a velocity v_0 in opposite directions, strike the ends of a rigid massless rod of length l, kept perpendicular to their velocity. The particles stick to the rod after the collision.Find the tension in rod during subsequent motion.



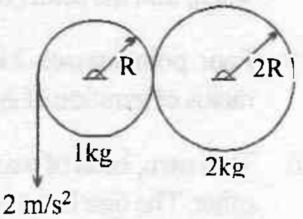
Q.12 A rigid body in shape of a triangle has v_A – 5 m/s ↓, v_B – 10 m/s ↓. Find velocity of point C.



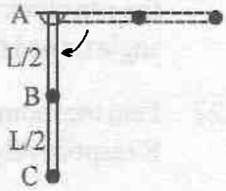
Q.13 A particle of mass 1 kg is moving with constant velocity of 10 m/s along the straight line $y = 7x + 4$. Find the angular momentum of the particle with respect to the point (3,4).

Q.14 A circular platform is mounted on a vertical frictionless axle. Its radius is $r = 2$ m and its moment of inertia is $I = 200$ kg-m^2. It is initially at rest. A 70 kg man stands on the edge of the platform and begins to walk along the edge at speed $v_0 = 1.0$ m/s relative to the ground. When the man has walked once around the platform so that he is at his original position on it, what is his angular displacement relative to ground.

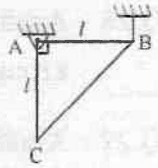
Q.15 Two discs A and B touch each other as in figure. A rope tightly wound on A is pulled down at 2 m/s^2. Find the friction force between A and B if slipping is absent



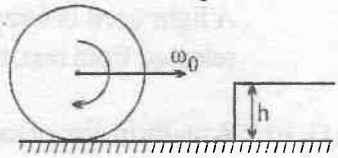
Q.16 Two masses each of m are attached at mid point B & end point C of massless rod AC which is hinged at A. It is released from horizontal position as shown. Find the force at hinge A when rod becomes vertical



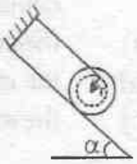
Q.17 An isosceles right triangular plate ABC of mass m is free to rotate in vertical plane about a fixed horizontal axis through A. It is supported by a string such that the side AB is horizontal. Find the reaction at the support A.



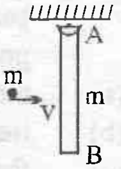
Q.18 A solid uniform sphere of radius R and mass M rolls without slipping with angular velocity ω_0 when it encounters a step of height 0.4 R. Find the angular velocity immediately after inelastic impact with the rough step.



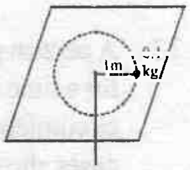
Q.19 A spool with a thread wound on it is placed on a smooth inclined plane set at an angle of 30° to the horizontal. The free of the thread is attached to the wall as shown. The mass of the spool is $m = 200$ g, its moment of inertia relative to its own axis is $I = 0.45$ gm^2, the radius of the wound thread layer is $r = 3$ cm. Find the acceleration of the spool axis .



Q.20 A uniform rod AB of length L and mass m is suspended freely at A and hangs vertically at rest when a particle of same mass m is fired horizontally with speed v to strike the rod at its mid point. If the particle is brought to rest after the impact. Then find the impulsive reaction at A.



Q.21 A ball of mass 0.1 kg rotates in a horizontal circle of radius 1m at constant speed 1 ms^{-1} on a frictionless table as shown in the figure. The ball is attached to a string which passes through a hole in the table. By pulling the string at the lower end, the radius of the path is reduced to 0.5 m. Find the new velocity of the ball and tension in the string.



Q.33 A solid sphere of mass m and radius R is placed on a smooth horizontal surface. A sudden blow is given horizontally to the sphere at a height h = 4R/5 above the centre line. If I is the impulse of the blow then find

(a) the minimum time after which the highest point B will touch the ground

(b) the displacement of the centre of mass during this internal.

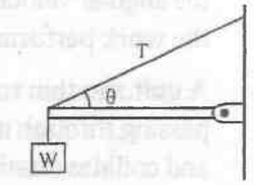
Q.34 A uniform ball of radius R rolls without slipping between two rails such that the horizontal distance is d between two contact points of the rail to the ball. If R=10cm, d=16cm and the angular velocity is 5rad/s then find the velocity of centre of mass of the ball.

Q.35 A cylinder of mass M and radius R is resting on a horizontal platform (which is parallel to the x-y plane) with its axis fixed along the y axis and free to rotate about its axis . The platform is given a motion in the x-direction given by $x = A\cos(\omega t)$. There is no slipping between the cylinder and platform. Find the maximum torque acting on the cylinder during its motion.

Q.36 In figure, the load W weighs 200N, $\theta = 37°$ and the beam has negligible weight. Find

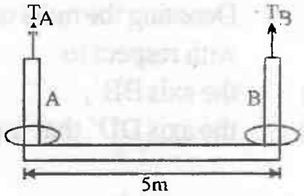
(a) the tension T in the cable and

(b) the horizontal and vertical components of the force that the pivot exerts on the beam.



Q.37 The door of an automobile is open and perpendicular to the body. The automobile starts with an acceleration of 2 ft/sec^2, and the width of the door is 30 inches. Treat the door as a uniform rectangle, and neglect friction to find the speed of its outside edge as seen by the driver when the door closes.

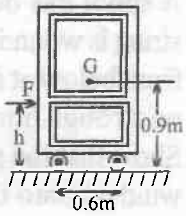
Q.38 A 5m beam weighing 250 kg is lowered by means of two cables unwinding from overhead cranes. as the beam approaches the ground the crane operater begins applying brakes to slow the unwinding motion. Knowing that the decelearation of cable A is 6 m/s^2 and the deceleration of cable B is 0.6 m/s^2, determine the tension in each cable. (g=9.8m/s^2)



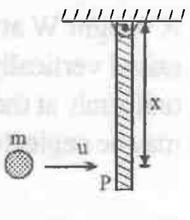
Q.39 A 20 kg cabinet is mounted on small casters that allow it to move freely ($\mu = 0$) on the floor. If a 100 N force is applied as shown, determine

(a) the acceleration of the cabinet,

(b) the range of values of h for which the cabinet will not tip.

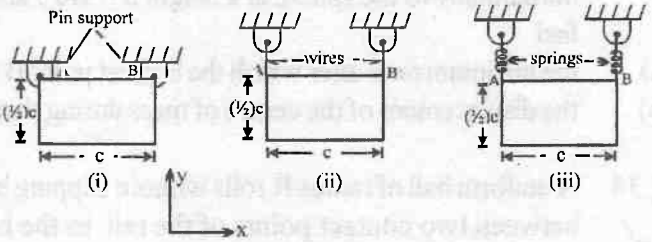


Q.40 One end of a uniform rod of mass M and length L is hinged to the ceiling such that it can rotate freely about, the hinge in vertical plane. The arrangement is shown in the figure. A ball of mass m moving horizontally with speed u hits the rod at point P separated by a distance x from hinge. For what value of x reaction of the hinge on the rod is minimum and what is it ?



EXERCISE-II

Q.1 A uniform plate of mass m is suspended in each of the ways shown. For each case determine immediately after the connection at B has been released ;

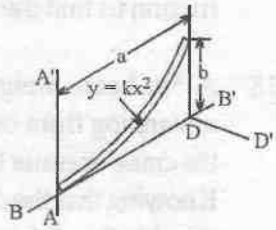


(a) the angular acceleration of the plate.
(b) the acceleration of its mass center.

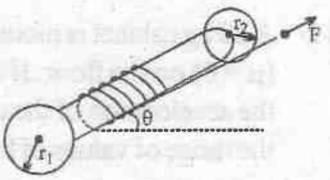
Q.2 A horizontally oriented uniform disc of mass M and radius R rotates freely about a stationary vertical axis passing through its centre. The disc has a radial guide along which can slide without friction a small body of mass m. A light thread running down through the hollow axle of the disc is tied to the body. Initially the body was located at the edge of the disc and the whole system is rotated with an angular velocity ω_0. Then by means of a force F applied to the lower end of the thread the body was slowly pulled to the rotation axis. Find
(a) the angular velocity of the system in its final state
(b) the work performed by the force F.

Q.3 A uniform thin rod of mass m=30kg and length L=0.80m is free to rotate about a horizontal axis O passing through its centre. A particle P of mass M=11.2kg falls vertically through a height h=36/245m and collides elastically with the rod at a distance of L/4 from O. At the instant of collision, the rod was stationary and was at angle α=37° with horizontal. Calculate
(i) ω of the rod just after collision
(ii) velocity (magnitude and direction) of particle P after collision [g=10m/s²]

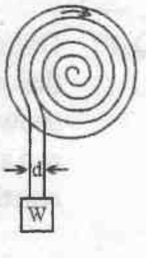
Q.4 The parabolic spandrel shown was cut from a thin, uniform plate. Denoting the mass of the spandrel by m, determine its moment of inertia with respect to
(a) the axis BB',
(b) the axis DD' that is perpendicular to the spandrel.



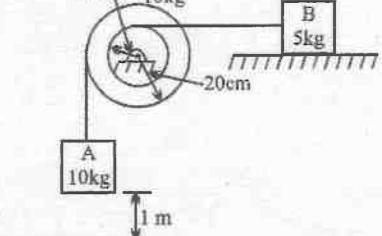
Q.5 A spool has outer wheels r_1 and a central bobbin of radius r_2. A string is wound on the bobbin, as shown in the figure, so as to emerge from below at an angle θ with respect to horizontal. The spool rests on a rough horizontal surface, and a force is applied to the string. Show that the string will unwind if $\cos\theta < r_2/r_1$ and that the spool will wind up onto the string if $\cos\theta > r_2/r_1$.



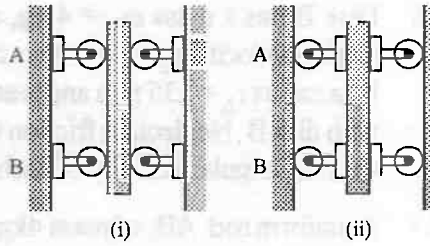
Q.7 A weight W attached to the end of a flexible rope of diameter d=0.75cm is raised vertically by winding the rope on a reel as shown. If the reel is turned uniformly at the rate of 2 r.p.s, what is the tension in rope. The inertia of rope may be neglected.



Q.8 The disk shown has weight 10 kg. Cylinder A and block B are attached to cords that are wrapped on the pulley as shown. The coefficient of kinetic friction between block B and the surface is 0.25. Knowing that the system is released from rest in the position shown, determine
(a) the velocity of cylinder A as it strikes the ground.
(b) the total distance that block B moves before coming to rest.



Q.9 A bar of mass m is held as shown between 4 disks, each of mass m' & radius r = 75 mm Determine the acceleration of the bar immediately after it has been released from rest, knowing that the normal forces exerted on the disks are sufficient to prevent any slipping and assuming that;



(a) m = 5 kg and m' = 2 kg .
(b) the mass m' of the disks is negligible.
(c) the mass m of the bar is negligible.

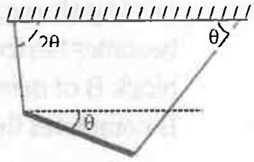
Q.10 Three small balls of the same mass, white (w), green(g) and blue(b), are fixed by weightless rods at the vertices of the equilateral triangle with side l. The system of ball is placed on a smooth horizontal surface and set in rotation about the center of mass with period T. At a certain instant, the blue ball tears away from the frame. Determine the distance L between the blue and the green ball after the time T.

Q.11 Show that, if a uniform heavy right circular cylinder of radius a be rotated about its axis, and laid gently on two rough horizontal rails at the same level and distant 2a sinα apart so that the axis of the cylinder is parallel to the rails, the cylinder will remain in contact with both rails if the coefficient of friction $\mu < \tan\alpha$, but will initially rise on one rail if $\mu > \tan\alpha$.

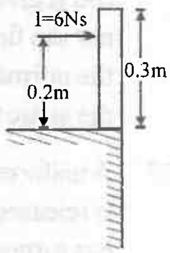


Q.12 A diwali cracker known as **sudarashan chakra** works on the principle of thrust. Consider such a toy the centre of which is hinged. The initial mass of the toy is M_0 and radius is R. The toy is in the shape of a spiral the turns of which are very close (it can be assumed as a disc). The gases are ejected tangentially from the end of the toy with a constant velocity u relative to the toy. Find the angular velocity of the toy when mass remains half.

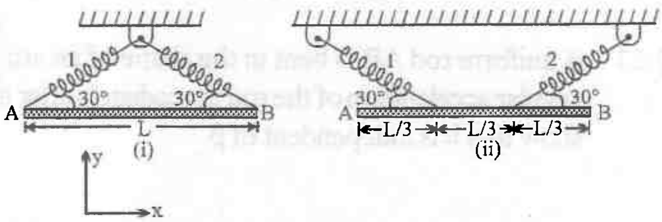
Q.13 A uniform rod is suspended by two light strings. The left string makes an angle 2θ and the rod makes angleθ with the horizontal. Find the angular acceleration of rod and tension in the left string just after the right string is cut.



Q.14 A uniform thin rod with a mass M = 0.60 kg and a length of 0.30 m stands on the edge of a frictionless table as shown in the figure. The rod is struck, a horizontal impulse blow at a point 0.20 m above the table top, driving the rod directly off the table. Determine the orientation of the rod and the position of its C.M. 1 s after the blow is struck. ($g = 9.8\ m/s^2$)

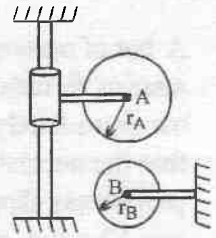


Q.15 A uniform slender bar AB of mass m is suspended from two springs as shown. If spring 2 breaks, determine at that instant;



(a) the angular acceleration of the bar.
(b) the acceleration of point A.
(c) the acceleration of point B.

Q.16 Disk B has a mass $m_B = 4$ kg, a radius $r_B = 90$ mm and an initial angular velocity $\omega_0 = 750$ r/min clockwise. Disk A has a mass $m_A = 6$ kg a radius $r_A = 135$ mm and is at rest when it is brought into contact with disk B. Neglecting friction in the bearings, determine, the final angular velocity of each disk.



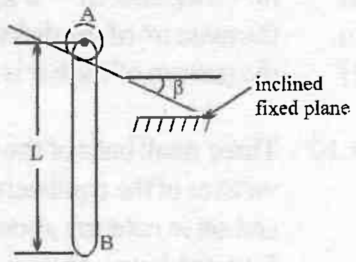
Q.17 A uniform rod AB, of mass 4kg and length L = 1.5 m is released from rest in the position shown. Knowing that β = 45°, determine the values (immediately after release) of

(a) the angular acceleration of the rod.

(b) the acceleration of end A.

(c) the reaction of the inclined plane at A.

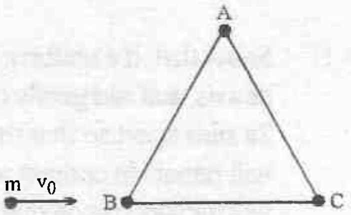
Neglect the mass of friction on the roller at A.



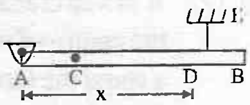
Q.18 Three particles A, B, C of mass m each are joined to each other by massless rigid rods to form an equilateral triangle of side a. Another particle of mass m hits B with a velocity v_0 directed along BC as shown. The colliding particle stops immediately after impact.

(i) Calculate the time required by the triangle ABC to complete half-revolution in its subsequent motion.

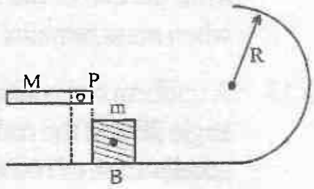
(ii) What is the net displacement of point B during this interval ?



Q.19 A slender bar AB is supported in a horizontal position as in figure. At what distance x from the hinge A should the vertical string DE be attached to the bar in order that, when it is cut, there will be no immediate change in the reaction at A.



Q.20 A rod of length R and mass M is free to rotate about a horizontal axis passing through hinge P as in figure . First it is taken aside such that it becomes horizontal and then released . At the lowest point the rod hits the block B of mass m and stops . Find the ratio of masses such that the block B completes the circle. Neglect any friction.



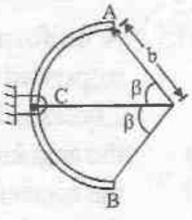
Q.21 A uniform rod of mass M is poised vertically on one of its end resting on a horizontal rough surface. If the rod is given a very slight impulse at its free end, it starts toppling down about its lower end which does not slip find

(a) the normal reaction by the floor on the rod when the rod turned through an angle θ=53°

(b) the static friction between the floor and the rod.

Q.22 A uniform rod of length 2a is placed horizontally on a fixed thin horizontal rail at right angles to the rail and is released from rest. Initially the centre of the rod was at a distance a/3 from rail. If the rod slips after it has turned through an angle θ find the coefficient of friction between the rod and the rail.

Q.23 A uniform rod AB is bent in the shape of an arc of circle. Determine the angular acceleration of the rod immediately after it is released from rest and show that it is independent of β.

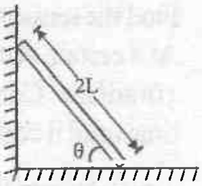


Q.24 Assume that the centre of mass of a girl crouching in a light swing has been raised to 1.2m. The girl has her centre of mass is 3.7m from the pivot of the swing while she is in the crouched position. The swing is released from rest and at the bottom of the arc the girl stands up instantaneously, thus raising her centre of mass 0.6m. Find the height of her centre of mass at the top of the arc.

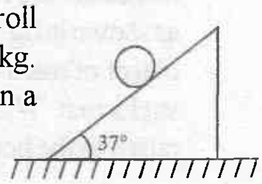
Q.25 A uniform ball of radius R rolls without slipping between two rails such that the horizontal distance is d between the two contact points of the rail to the ball. (a) Show that at any instant, velocity of centre of mass is given as : $v_{cm} = \omega\sqrt{R^2 - \frac{d^2}{4}}$

Discuss the above expression in the limits d=0 and d=2R. (b) For a uniform ball starting from rest and decending a vertical distance h while rolling without slipping down a ramp, $v_{cm} = \sqrt{\frac{10gh}{7}}$, if the ramp is replaced with two rails, show that : $v_{cm} = \sqrt{\frac{10gh}{5 + \frac{2}{1 - d^2/4R^2}}}$.

Q.26 A plank of length 2L, leans vertically against a wall. It starts to slip downward without friction. Show that the top of the plank loses contact with the wall when it is at two-thirds of its initial height

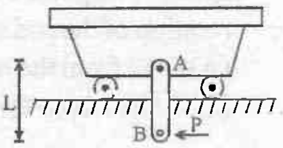


Q.27 A solid metallic cylinder of mass m = 1 kg and radius R = 20 cm is free to roll (without sliding) over the inclined surface of a wooden wedge of mass M = 0.28 kg. Surface of wedge is inclined at 37^0 with the horizontal and the wedge lies on a smooth horizontal floor. When the system is released from rest, calculate



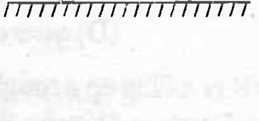
(i) acceleration of the wedge,
(ii) angular acceleration of the cylinder and
(iii) force of interaction between cylinder and the wedge . ($g = 10\ ms^{-2}$)

Q.28 A uniform slender bar AB of mass m is suspended as shown from a small cart of the same mass m. Neglecting the effect of friction, determine the acceleration of points A and B immediately after a horizontal force P has been applied at B.



Q.29 A solid spherical ball which rests in equilibrium at the interior bottom of a fixed spherical globe is perfectly rough. the ball is struck a horizontal blow of such magnitude that the initial speed of its centre is v. Prove that, if v lies between $(10\ dg/7)^{1/2}$ and $(27\ dg/7)^{1/2}$, the ball will leave the globe, d being the difference between the radii of the ball and globe.

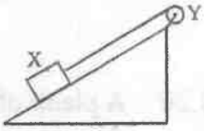
Q.30 A 240 mm radius cylinder of mass 8 kg rests on a 3 kg carriage. The system is at rest when a force P of magnitude 10 N is applied as shown for 1.2 s. Knowing that the cylinder rolls without sliding on the carriage and neglecting the mass of the wheels of the carriage determine the resulting velocity of (a) the carriage, (b) the center of the cylinder.



EXERCISE–III

Q.1 A uniform thin rod of mass M and length L is standing vertically along the y-axis on a smooth horizontal surface with its lower end at the origin (0,0). a slight disturbance at t=0 causes the lower end to slip on the smooth surface along the positive x axis and the rod starts falling (a) What is the path followed by the centre of mass of the rod during its fall (b) Find the equation of trajectory of a point on the rod located at a distance r from the lower end. What is the shape the of the path of this point. [JEE' 93]

Q.2 A block X of mass 0.5kg is held by a long massless string on a frictionless inclined plane of inclination 30° to the horizontal. The string is wound on a uniform solid cylindrical drum Y of mass 2kg and of radius 0.2 m as shown in the fig. The drum is given an initial angular velocity such that the block X starts moving up the plane.



(i) Find the tension in the string during the motion

(ii) At a certain instant of time the magnitude of the angular velocity of Y is 10rad/sec. Calculate the distance travelled by X from that instant of time until it comes to rest. [JEE' 94]

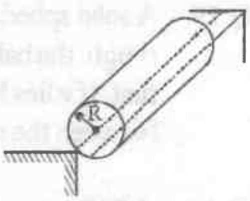
Q.3 Two uniform thin rods A and B of length 0.6m each and masses 00.01kg and 0.02kg respective are rigidly joined and to end. The combination is pivoted at the lighter end P as shown in fig. such that it can freely rotate about the point P in a vertical plane. A small object of mass 0.05kg moving horizontally hits the lower end of the combination and sticks to it. What should be the velocity of the object so that the system could just be raised to the horizontal position. [JEE' 94]



Q.4 Two point masses of 0.3kg and 0.7kg are fixed at the ends of a rod which is of length 1.4m and of negligible mass. The rod is set rotating about an axis perpendicular to its length with a uniform angular speed. The point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum is located at a distance of [JEE' 95]

(A) 0.42 from the mass of 0.3kg (B) 0.70 m from the mass of 0.7kg
(C) 0.98m from the mass of 0.3kg (D) 0.98m from the mass of 0.7kg

Q.5 A rectangular rigid fixed block has a long horizontal edge. A solid homogeneous cylinder of radius R is placed horizontally at rest with its length parallel to the edge such that the axis of the cylinder and the edge of the block are in the same vertical plane as shwon in figure. there is sufficient friction present at the edge so that a very small displacement cause the cylinder to roll of the edge without slipping. Determine



(a) the angle θ_c through which the cylinder rotates before it leaves contact with the edge,

(b) the speed of the centre of mass of the cylinder before leaving contact with the edge, and

(c) the ratio of the translational to rotational kinetic energies of the cylinder when its centre of mass is in horizontal line with the edge. [JEE' 95]

Q.6 A mass m moving with a constant velocity along a line parallel to the x axis, away from the origin. Its angular momentum with respect to the origin. [JEE' 97]

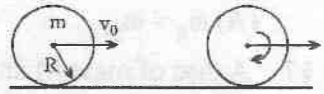
(A) is zero (B) remains constant
(C) goes on increasing (D) goes on decreasing

Q.7 A uniform disk of mass m and radius R is rolling up a rough inclined plane which makes an angle of 30° with the horizontal. If the coefficient of static and kinetic friction are each equal to μ and the only forces acting are gravitational and frictional, then the magnitude of the frictional force acting on the disk is ____ and its direction is ____ (write up or down) the inclined plane. [JEE' 97]

Q.8 A uniform disk of mass m and radius R is projected horizontally with velocity v_0 on a rough horizontal floor so that it starts off with a purely sliding motion at t=0. After t_0 seconds it acquires a purely rolling motion as shown in figure.

(i) Calculate the velocity of the centre of mass of the disk at t_0.

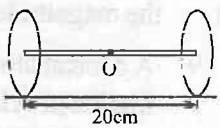
(ii) Assuming the coefficient of friction to be μ calculate t_0. Also calculate the work done by the frictional force as a function of time and the total work done by it over a time t much longer than t_0. [JEE' 97]



Q.9 Two thin circular disks of mass 2kg and radius 10cm each are joined by a rigid massless rod of length 20cm. The axis of the rod is along the perpendicular to the planes of the disks through their centre. The object is kept on a truck in such a way that the axis of the object is horizontal and perpendicular to the direction of motion of the truck. Its friction with the floor of the truck is large enough so that the object can roll on the truck without slipping. Take x-axis as the direction of motion of the truck and z-axis as the vertically upwards direction. If the truck has an acceleration of $9 m/s^2$ calculate :

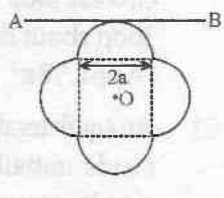
(a) the force of friction on each disk

(b) The magnitude and the direction of the frictional torque acting on each disk about the centre of mass O of the object. Express the torque in the vector form of unit vectors in the x-y and z directions. [JEE' 97]



Q.10 A rod of weight w is supported by two parallel knife edges A and B is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at a distance x from A. The normal reaction on A is ____ and on B is ____ [JEE' 97]

Q.11 A symmetric lamina of mass M consists of a square shape with a semicircular section over each of the edge of the square as in fig. The side of the square is 2a. The moment of inertia of the lamina about an axis through its centre of mass and perpendicular to the plane is $1.6Ma^2$. The moment of inertia of the lamina about the tangent AB in the plane of lamina is ______ [JEE' 97]



Q.12 Let I be the moment of inertia of a uniform square plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to

(A) I (B) $I \sin^2\theta$ (C) $I\cos^2\theta$ (D) $I\cos^2(\theta/2)$ [JEE' 98]

Q.13 The torque $\vec{\tau}$ on a body about a given point is found to be equal to $\vec{A} \times \vec{L}$ where $\vec{A}$ is a constant vector and $\vec{L}$ is the angular momentum of the body about that point. From this it follows that [JEE' 98]

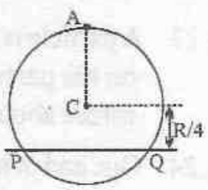
(A) $d\vec{L}/dt$ is perpendicular to $\vec{L}$ at all instants of time

(B) the components of $\vec{L}$ in the direction of $\vec{A}$ does not change with time

(C) the magnitude of $\vec{L}$ does not change with time

(D) $\vec{L}$ does not change with time

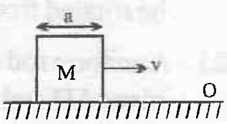
Q.14 A uniform circular disc has radius R and mass m. A particle also of mass m is fixed at a point A on the wedge of the disc as in fig. The disc can rotate freely about a fixed horizontal chord PQ that is at a distance R/4 from the centre C of the disc. The line AC is perpendicular to PQ. Initially the disc is held vertical with the point A at its highest position. It is then allowed to fall so that it starts rotating about PQ. Find the linear speed of the particle at it reaches its lowest position. [JEE' 98]



Q.15 A cubical block of side a is moving with velocity v on a horizontal smooth plane as shown. It hits a ridge at point O. The angular speed of the block after it hits O is:

(A) 3v/4a (B) 3v/2a

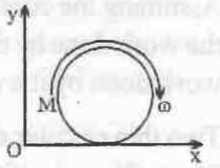
(C) $\sqrt{3v}/\sqrt{2a}$ (D) zero [JEE' 99]



Q.16 A smooth sphere A is moving on a frictionless horizontal plane with angular speed ω and centre of mass velocity v. It collides elastically and head on with an identical sphere B at rest. Neglect friction everywhere. After the collision, their angularspeeds are ω_A and ω_B, respectively. Then [JEE' 99]

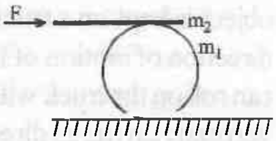
(A) $\omega_A < \omega_B$ (B) $\omega_A = \omega_B$ (C) $\omega_A = \omega$ (D) $\omega_B = \omega$

Q.17 A disc of mass M and radius R is rolling with angular speed w on a horizontal as shown. The magnitude of angular momentum of the disc about the origin O is: [JEE' 99]



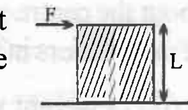
(A) $(1/2)MR^2\omega$ (B) $MR^2\omega$
(C) $(3/2)MR^2\omega$ (D) $2MR^2\omega$

Q.18 A man pushes a cylinder of mass m_1 with the help of a plank of mass m_2 as shown. There is no slipping at any contact. The horizontal component of the force applied by the man is F. Find



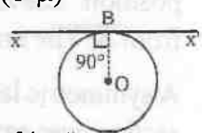
(a) the accelerations of the plank and the center of mass of the cylinder, and
(b) the magnitudes and directions of frictional forces at contact points. [JEE' 99]

Q.19 A cubical block of side L rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the block as shown. If the coefficient of frictionis sufficiently high so that the block does not slide before toppling, the minimum force required to topple the block is: [JEE'(Scr)'2000]



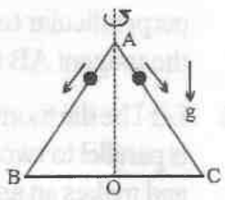
(A) infinitesimal (B) mg/4 (C) mg/2 (D) mg(1-μ)

Q.20 A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX' is: [JEE'(Scr)'2000]



(A) $\rho L^3/8\pi^2$ (B) $\rho L^3/16\pi^2$ (C) $5\rho L^3/16\pi^2$ (D) $3\rho L^3/8\pi^2$

Q.21 An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at AO. Then, the beads are released from rest simultaneously and allowed to slide down, one along AB and the other AC as shown. Neglecting frictional effects, the quantities that are conserved as the beads slide down, are: [JEE'(Scr)'2000]



(A) angula velocity and total energty (kinetic and potential)
(B) total angular momentum and total energy
(C) angular velocity and moment of inertia about the axis of rotaiton.
(D) total angular momentum and moment of inertia about the axis of rotation.

Q.22 A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m travelling along the surface hits the end 'A' of the rod with a velocity v_0 in the direction perpendicular to AB. The collision is completely elastic. After the collision the particle comes to rest.

(a) Find the ratio m/M.
(b) A point P on the rod is at rest immediately after the collision. Find the distance AP.
(c) Find the linear speed of the point P at a time $\pi L/(3v_0)$ after the collision. [JEE' 2000]

Q.23 A particle is placed at a corner P of a cube of side 1 meter. Forces of magnitudes 2, 3, and 5 kg. wt. act on the particle long the diagonals of the faces passing through the point P. Find the moment of these forces about the corner opposite to P. [REE 2000]

Q.24 One end of a uniform rod of mass M and length L is supported by a frictionless hinge which can withstand a tension of 1.75 Mg. The rod is free to rotate in a vertical plane. To what maximum angle should the rod be rotated from the vertical position so that when left, the hinge does not break. [REE 2000]

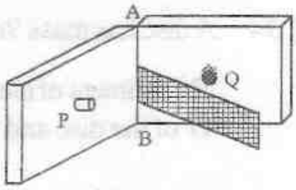
Q.25 A uniform rod AB of length 10 meters and weight 6kg.wt. is resting with its end A on a smooth horizontal plane AD and end B on a smooth plane DB inclined at angle 60^0 with the horizontal. The rod is kept in equilibrium by tying a string DP to a point P of the rod. If the length of the string is equal to AP and AD = BD, find the tension in the string. [REE'2000]

Q.26 Two heavy metallic plates are joined together at 90° to each other. A laminar sheet of mass 30 Kg is hinged at the line AB joining the two heavy metallic plates. The hinges are frictionless. The moment of inertia of the laminar sheet about an axis parallel to AB and passing through its centre of mass is 1.2 Kg-m². Two rubber obstacles P and Q are fixed, one on each metallic plate at a distance 0.5 m from the line AB. This distance is chosen so that the reaction due to the hinges on the laminar sheet is zero during the impact. Initially the laminar sheet hits one of the obstacles with an angular velocity 1 rad/s and turns back. If the impulse on the sheet due to each obstacle is 6 N–s.

(a) Find the location of the centre of mass of the laminar sheet from AB.

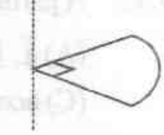
(b) At what angular velocity does the laminar sheet come back after the first impact?

(c) After how many impacts, does the laminar sheet come to rest? [JEE' 2001]



Q.27 One quarter sector is cut from a uniform circular disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the centre of the original disc. Its moment of inertia about the axis of rotation is [JEE'(Scr)2001]

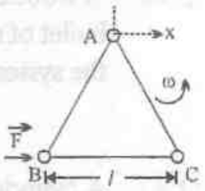
(A) $\frac{1}{2}MR^2$ (B) $\frac{}{4}MR^2$ (C) $\frac{1}{\circ}MR^2$ (D) $\sqrt{2}MR^2$



Q.28 Three particles A, B and C, each of mass m, are connected to each other by three massless rigid rods to form a rigid, equilateral triangular body of side l. This body is placed on a horizontal frictionless table (x-y plane) and is hinged to it at the point A so that it can move without friction about the vertical axis through A (see figure). The body is set into rotational motion on the table about A with a constant angular velocity ω.

(a) Find the magnitude of the horizontal force exerted by the hinge on the body.

(b) At time T, when the side BC is parallel to the x-axis, a force F is applied on B along BC (as shown). Obtain the x-component and the y-component of the force exterted by the hinge on the body, immediately after time T. [JEE' 2002]



Q.29 A particle is moving in a horizontal uniform circular motion. The angular momentum of the particle is conserved about the point : [JEE'(Scr)2003]

(A) Centre of the circle (B) Outside the circle
(C) Inside the circle (D) Point on circumference

Q.30 Two particles each of mass M are connected by a massless rod of length l. The rod is lying on the smooth sufrace. If one of the particle is given an impulse MV as shown in the figure then angular velocity of the rod would be : [JEE'(Scr)2003]

(A) v/l (B) $2v/l$ (C) $v/2l$ (D) None



Q.31 A disc is rolling (without slipping) on a horizontal surface. C is its center and Q and P are two points equidistant from C. Let V_P, V_Q and V_C be the magnitude of velocities of points P, Q and C respectively, then [JEE' 2004 (Scr)]

(A) $V_Q > V_C > V_P$ (B) $V_Q < V_C < V_P$
(C) V_C V_P, V_C 1 (D) $V_Q < V_C > V_P$

Q.32 A child is standing with folded hands at the center of a platform rotating about its central axis. The kinetic energy of the system is K. The child now stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is [JEE' 2004 (Scr)]

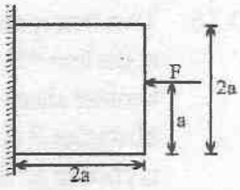
(A) 2K (B) $\frac{K}{2}$ (C) K (D) 4K

$= \quad = \frac{\ }{2} V_P$

Q.33 A block of mass m is held fixed against a wall by a applying a horizontal force F. Which of the following option is incorrect:

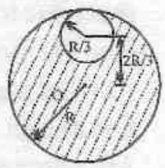
(A) friction force = mg (B) F will not produce torque

(C) normal will not produce torque (D) normal reaction = F



[JEE'2005 (Scr)]

Q.34 A disc has mass 9m. A hole of radius $\frac{R}{3}$ is cut from it as shown in the figure. The moment of inertia of remaining part about an axis passing through the centre 'O' of the disc and perpendicular to the plane of the disc is:



(A) 8 mR^2 (B) 4 mR^2 (C) $\frac{40}{9}$ mR^2 (D) $\frac{37}{9}$ mR^2

[JEE'2005 (Scr)]

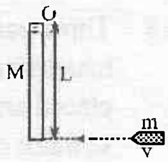
Q.35 A particle moves in circular path with decreasing speed. Which of the following is correct

(A) $\vec{L}$ is constant (B) only direction of $\vec{L}$ is constant

(C) acceleration $\vec{a}$ is towards the centre (D) it will move in a spiral and finally reach the centre

[JEE'2005 (Scr)]

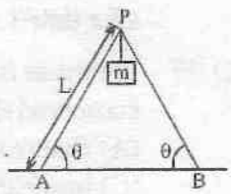
Q.36 A wooden log of mass M and length L is hinged by a frictionless nail at O. A bullet of mass m strikes with velocity v and sticks to it. Find angular velocity of the system immediately after the collision about O.



[JEE 2005]

Q.37 A cylinder of mass m and radius R rolls down an inclined plane of inclination θ. Calculate the linear acceleration of the axis of cylinder. [JEE 2005]

Q.38 Two identical ladders, each of mass M and length L are resting on the rough horizontal surface as shown in the figure. A block of mass m hangs from P. If the system is in equilibrium, find the magnitude and the direction of frictional force at A and B.



[JEE 2005]

ANSWER KEY

EXERCISE–I

Q.1 $\dfrac{mu^3 \sin^2\theta\cos\theta}{2g}$ Q.2 $\sqrt{\dfrac{3}{7}gh}$ Q.3 $\sqrt{16rv^2/g}$ Q.4 $2v_0/L$

Q.5 $5\ m/s^2$ Q.6 $4F^2/M$ Q.7 $\omega/3,\ \dfrac{\sqrt{37}}{3}m\omega R$ Q.8 $\dfrac{(e_1+e_2)^2 h}{4}$

Q.9 $\dfrac{l^2}{12x}$ Q.10 $2m\omega^3 r^2$ Q.11 $\dfrac{2mv_0^2}{l}$ Q.12 $5\sqrt{5}$ m/s

Q.13 $21\sqrt{2}$ kg m²/s, remains constant Q.14 $\dfrac{5\pi}{6}$ Q.15 2 N

Q.16 $\dfrac{28mg}{5}$ Q.17 $2mg/3$ Q.18 $\dfrac{5\omega_0}{7}$ Q.19 $1.4\ ms^{-2}$

Q.20 $\dfrac{mv}{4}$ Q.21 $2\ ms^{-1}$, 0.8 N Q.22 $\dfrac{\sqrt{3}}{8}(-\hat{k})$ N-m Q.23 $\dfrac{1}{3}$ m

Q.24 $\mu MgL/4$ Q.25 $\dfrac{10}{\sqrt{2}}$ cm Q.26 $\dfrac{4\pi}{5}$ Q.27 $M(R^2+r^2)/2$

Q.28 $\dfrac{a}{b}=\dfrac{15}{14}$ and $\dfrac{b}{c}=\dfrac{4}{3}$ Q.29 5 N Q.30 (a) $\omega/3$, (b) $\dfrac{\sqrt{37}}{3}m\omega R$, (c) $\dfrac{\sqrt{37}}{3}m\omega R$

Q.31 (a) $\dfrac{72\,v}{55\,\ell}$, (b) $\dfrac{\pi\ell}{3}$, (c) $\dfrac{24mV}{55}$ Q.32 a^2/b^2

Q.33 (a) $t=\dfrac{\pi Rm}{2I}$; (b) $s=\dfrac{\pi R}{2}$ Q.34 0.3 m/s

Q.35 $(1/2)MRA\,\omega^2$ Q.36 $T=1000/3N,\ F_x = 800/3N,\ F_y = 0$ Q.37 $\sqrt{15}$ ft/sec

Q.38 $T_A = 1750$ N ; $T_B = 1525$ N Q.39 (a) 5 m/s² →, (b) 0.3 < h < 1.5 m Q.40 x = 2L/3

EXERCISE–II

Q.1 (i)(a) $\dfrac{1.2g}{c}$ (cw) (b) $-0.3(\hat{i}+2\hat{j})g$ (ii)(a) $24g/17c$ (cw) (b) $12g/17\downarrow$ (iii)(a) $2.4g/c$(cw) (b) $0.5g\downarrow$

Q.2 $\omega=\left(1+\dfrac{2m}{M}\right)\omega_o$, $W=\dfrac{1}{2}m\omega_o^2R^2\left(1+\dfrac{2m}{M}\right)$ Q.3 3 rad/s, 9/7 m/s along horizontal

Q.4 (a) $mb^2/7$, (b) $\dfrac{m(7a^2+10b^2)}{70}$ Q.6 $\sqrt{\dfrac{14}{3}gR}$

Q.7 1.018 W Q.8 (a) $\sqrt{\dfrac{150}{13}}$ m/s, (b) $\dfrac{44}{13}$ m

Q.9 (i) (a) $5g/9\downarrow$ (b) $g\downarrow$ (c) 0 (ii) (a) $\dfrac{13g}{17}\downarrow$ (b) $g\downarrow$ (c) $\dfrac{2g}{3}\downarrow$

Q.10 $\dfrac{l}{2}\sqrt{1+\sqrt{3}\,\pi+3\pi^2}$

Q.12 $w=\dfrac{4u}{R}\left(\sqrt{2}-1\right)$ Q.13 $T=2mg\sin\theta\cos\theta/(1+3\sin^2\theta)$, $\alpha=6T\sin\theta/ml$

Q.14 [10, – 4.75 m] w.r.t. initial position of lower end of rod, $\frac{200}{3}$ rad with upward vertical

Q.15 (i) (a) 3 g/L (cw) (b) $\left(\frac{\sqrt{3}}{2}\hat{i}+\hat{j}\right)$ g = 1.323 g ∠ 49.1° (c) $\left(\frac{\sqrt{3}}{2}\hat{i}-2\hat{j}\right)$ g = 2.18 g ∠ –66.6°

(ii) (a) g/L (cw) (b) $-\left(\frac{\sqrt{3}}{2}\right)$ g $\hat{i}$ (c) $-\left(\frac{\sqrt{3}}{2}\hat{i}+\hat{j}\right)$ g = 1.323 g ∠ – 130.9°

Q.16 w_A = 200 rpm (ccw), w_B = 300 rpm (cw)

Q.17 8 rad/s², $8\sqrt{2}$ m/s², $8\sqrt{2}$ N

Q.18 (i) $t=\frac{6a\pi}{\sqrt{3}v_0}$; (ii) $s=\frac{a}{\sqrt{3}}\sqrt{1+(2\pi+\sqrt{3})^2}$

Q.19 2*l*/3

Q.20 $\frac{M}{m}=\sqrt{15}$

Q.21 $\frac{4mg}{25}$, $\frac{3mg}{25}$

Q.22 2 tanθ Q.23 g/2b Q.24 2.3 m

Q.27 (i) 3.75 ms^{-2}, (ii) 30 rad sec^{-2}, (iii) Normal reaction=5.75 N, friction = 3.00N Interaction force = 6.49 N

Q.28 (a) 2P/5m= a_A →, a_B = 16P/5m ←

Q.30 (a) 0.706 m/s →, (b) 1.235 m/s →

EXERCISE–III

Q1. x=0, $\frac{x^2}{[L/2-r]^2}+\frac{y^2}{r^2}=1$

Q2. 1.63 N, 1.224 m

Q3. 6.3m/s

Q.4 C

Q.5 (a) $\theta_C = \cos^{-1}(4/7)$, (b) $v=\sqrt{4/7\,gR}$, (c) $K_T/K_R = 6$

Q6. B

Q.7 Mg sinθ/3, up

Q.8 (i) $2v_0/3$, (ii) $t=v_0/3\mu g$, $W=\frac{1}{2}[3\mu m g^2t^2-2\mu m g t v_0]$ $(t<t_0)$, $W=-\frac{1}{6}mv_0^2$ $(t>t_0)$

Q9. 6N, $-0.6\hat{j}\pm0.6\hat{k}$

Q10. w(d – x)/d, wx/d

Q11. 4.8Ma²

Q.12 A

Q.13 A, B, C

Q14. $v=\sqrt{5gR}$

Q15. A

Q16. C

Q17. C

Q18. $a_c=\frac{4F}{(3m_1+8m_2)}$, $a_p=\frac{8F}{(3m_1+8m_2)}$; $f_1=\frac{3m_1F}{(3m_1+8m_2)}$, $f_2=\frac{m_1F}{(3m_1+8m_2)}$

Q19. C

Q.20 D

Q21. B

Q22. (a) $\frac{m}{M}=\frac{1}{4}$; (b) $x=\frac{2L}{3}$; (c) $\frac{v_0}{2\sqrt{2}}$

Q.23 $\sqrt{7}$ kg wt m

Q.24 60°

Q.25 $\frac{3mg}{4}$

Q26. (a) l = 0.1m; (b) w′ = 1rad/s ; (c) laminar sheet will never come to rest

Q27. A

Q.28 (a) $\sqrt{3}\,m\omega^2 l$, (b) F_x = F/4, $F_y=\sqrt{3}\,m\omega^2 l$

Q.29 A

Q.30 A

Q.31 A

Q.32 B

Q.33 C

Q.34 B

Q.35 B

Q.36 $\omega=\frac{3mv}{(3m+M)L}$

Q.37 $a_{axis}=\frac{2g\sin\theta}{3}$

Q.38 $f=(M+m)\,g\frac{\cot\theta}{2}$

Q.22 A particle of mass 0.1 kg is projected with a velocity $\sqrt{10}$ m/s making an angle of 30° with the horizontal in the xy plane. Find the moment of the weight of the particle about the point of projection when it is at one fourth of its range.

Q.23 A solid cylinder is released from rest from the top of an inclined plane of inclination 60° where friction coefficient varies with distance x as $\mu = \frac{2-3x}{\sqrt{3}}$. Find the distance travelled by the cylinder on incline before it starts slipping.

Q.24 A uniform rod placed on a horizontal floor and imparted an angular velocity about a vertical axis passing through its mid point. The mass of the rod is M, length L and friction coefficient with the surface is μ. Then, find the total retarding torque of friction forces.

Q.25 Four point masses 2 kg, 4 kg, 6 kg & 8 kg are placed at four corners of a square of side 10 cm. Find the radius of gyration of system about an axis passing through centre O and perpendicular to square plane.

Q.26 Two men, each of mass 75 kg, stand on the rim of a horizontal large disc, diametrically opposite to each other. The disc has a mass 450 kg and is free to rotate about its axis. Each man simultaneously start along the rim clockwise with the same speed and reaches their original starting points on the disc. Find the angle turned through by the disc with respect to the ground.

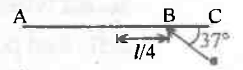
Q.27 Find the moment of inertia of a disc of uniform thickness of mass M and internal and external radii r and R respectively about an axis through it centre perpendicular to the plane of the disc.

Q.28 A solid sphere of radius 3R, a solid disc of radius 2R and a ring of radius R (all are of mass m) roll down a rough inclined plane. Their acclerations are a, b and c respectively. Find the ratio of a/b and b/c.

Q.29 A uniform disc of radius 1m and mass 2kg is mounted on an axle supported on fixed frictionless bearings. A light cord is wrapped around the rim of the disc and a mass of 1kg is tied to the free end. If it is released from rest, then find the tension in the cord.

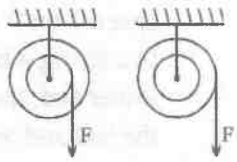
Q.30 A uniform disc of mass m and radius R rotates about a fixed vertical axis passing through its centre with angular velocity ω. A particle of same mass m and having velocity 2ωR towards centre of the disc collides with the disc moving horizontally and sticks to its rim. Find
(a) the angular velocity of the disc.
(b) the impulse on the particle due to disc.
(c) the impulse on the disc due to hinge.

Q.31 A rod AC of length L and mass m is kept on a horizontal smooth plane. It is free to rotate and move. A particle of same mass m moving with velocity v strikes rod at point B which is at a distance L/4 from mid point making angle 37° with the rod. The collision is elastic. After collision find



(a) the angular velocity of the rod.
(b) the distance which centre of the rod will travel in the time in which it makes half rotation.
(c) the impulse of the impact force.

Q.32 A person pulls along a rope wound up around a pulley with a constant force F for a time interval of t seconds. If a and b are the radii of the inner and the outer circumference (a < b), then find the ratio of work done by the person in the two cases shown in the figure is W_1/W_2.



Case I Case II

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (P,Q,R,S)

IIT-JEE SCREENING 2007

QUESTION BANK ON

ROTATIONAL DYNAMICS

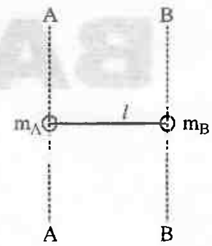
Time Limit : 3 Sitting Each of 90 minutes. duration approx.

Objective Question Bank On Rotational Dynamics

There are 82 questions in this question bank.

Q.1 Three bodies have equal masses m. Body A is solid cylinder of radius R, body B has a square lamina of side R, and body C has a solid spherte of radius R. Which body has the smallest moment of inertia about an axis passing through their centre of mass and perpendicular to the plane (in case of lamina)
(A) A (B) B (C) C (D) A and C both

Q.2 A point mass m_A is connected to a point mass m_B by a massless rod of length l as shown in the figure. It is observed that the ratio of the moment of inertia of the system about the two axes BB and AA, which is parallel to each other and perpendicular to the rod is $\frac{I_{BB}}{I_{AA}} = 3$. The distance of the centre of mass of the system from the mass A is



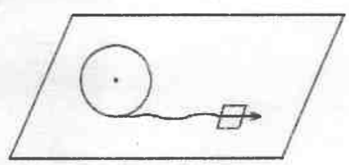
(A) $(3/4)\,l$ (B) $(2/3)\,l$
(C) $(1/2)\,l$ (D) $(1/4)\,l$

Q.3 A horizontal force F = mg/3 is applied on the upper surface of a uniform cube of mass 'm' and side 'a' which is resting on a rough horizontal surface having $\mu_S = 1/2$. The distance between lines of action of 'mg' and normal reaction 'N' is :
(A) a/2 (B) a/3 (C) a/4 (D) None

Q.4 For the same total mass which of the following will have the largest moment of inertia about an axis passing through its centre of mass and perpendicular to the plane of the body
(A) a disc of radius a (B) a ring of radius a
(C) a square lamina of side 2a (D) four rods forming a square of side 2a

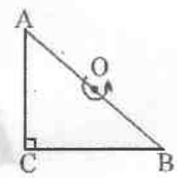
Q.5 A straight rod of length L is released on a frictionless horizontal floor in a vertical position. As it falls + slips, the distance of a point on the rod from the lower end, which follows a quarter circular locus is
(A) L/2 (B) L/4 (C) L/8 (D) None

Q.6 A block of mass m is attached to a pulley disc of equal mass m, radius r by means of a slack string as shown. The pulley is hinged about its centre on a horizontal table and the block is projected with an initial velocity of 5 m/s. Its velocity when the string becomes taut will be



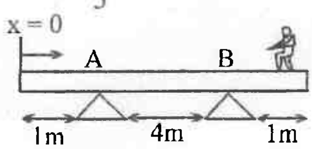
(A) 3 m/s (B) 2.5 m/s
(C) 5/3 m/s (D) 10/3 m/s

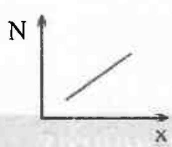
Q.7 Find the moment of inertia of a plate cut in shape of a right angled triangle of mass M, side AC = BC = a about an axis perpendicular to the plane of the plate and passing through the mid point of side AB

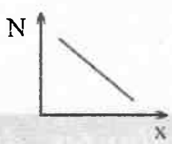


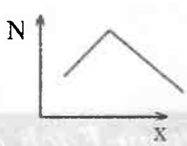
(A) $\frac{Ma^2}{12}$ (B) $\frac{Ma^2}{6}$ (C) $\frac{Ma^2}{3}$ (D) $\frac{2Ma^2}{3}$

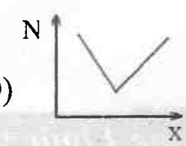
Q.8 A man can move on a plank supported symmetrically as shown. The variation of normal reaction on support A with distance x of the man from the end of the plank is best represented by :



(A) 

(B) 

(C) 

(D) 

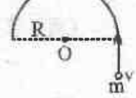
Q.9 A uniform rod of mass m and length l hinged at its end is released from rest when it is in the horizontal position. The normal reaction at the hinge when the rod becomes vertical is :

(A) $\frac{Mg}{2}$ (B) $\frac{3Mg}{2}$ (C) $\frac{5Mg}{2}$ (D) 2 Mg

Q.10 Two particles of mass m each are fixed at the opposite ends of a massless rod of length 5m which is oriented vertically on a smooth horizontal surface and released. Find the displacement of the lower mass on the ground when the rod makes an angle of 37° with the vertical.

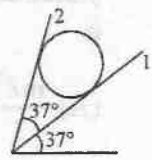
(A) 1.5 m (B) 2 m (C) 2.5 m (D) 3.5 m

Q.11 A small bead of mass m moving with velocity v gets threaded on a stationary semicircular ring of mass m and radius R kept on a horizontal table. The ring can freely rotate about its centre. The bead comes to rest relative to the ring. What will be the final angular velocity of the system?



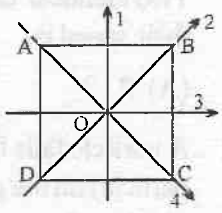
(A) v/R (B) 2v/R
(C) v/2R (D) 3v/R

Q.12 A sphere of mass m is held between two smooth inclined walls. The normal reaction of the wall 2 is equal to



(A) mg (B) mg sin 74°
(C) mg cos 74° (D) None

Q.13 ABCD is a square plate with centre O. The moments of inertia of the plate about the perpendicular axis through O is I and about the axes 1, 2, 3 & 4 are I_1, I_2, I_3 & I_4 respectively. It follows that :

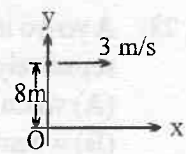


(A) $I_2 = I_3$ (B) $I = I_1 + I_4$
(C) $I = I_2 + I_4$ (D) $I_1 = I_3$

Q.14 A body weighs 6 gms when placed in one pan and 24 gms when placed on the other pan of a false balance. If the beam is horizontal when both the pans are empty, the true weight of the body is :

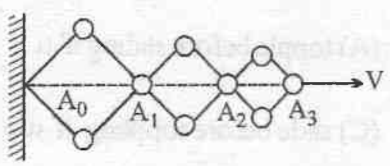
(A) 13 gm (B) 12 gm (C) 15.5 gm (D) 15 gm

Q.15 A particle starts from the point (0m, 8m) and moves with uniform velocity of $3\hat{i}$ m/s. After 5 seconds, the angular velocity of the particle about the origin will be :



(A) $\frac{8}{289}$ rad/s (B) $\frac{3}{8}$ rad/s (C) $\frac{24}{289}$ rad/s (D) $\frac{8}{17}$ rad/s

Q.16 A hinged construction consists of three rhombs with the ratio of sides 5:3:2. Vertex A_3 moves in the horizontal direction at a velocity v. Velocity of A_2 is



(A) 2.5 V (B) 1.5 V
(C) $\frac{2}{3}$ V (D) 0.8 V

Q.17 A block of mass m moves on a horizontal rough surface with initial velocity v. The height of the centre of mass of the block is h from the surface. Consider a point A on the surface.

(A) angular momentum about A is mvh initially
(B) the velocity of the block decreases at time passes.
(C) torque of the forces acting on block is zero about A
(D) angular mometum is not conserved about A.

Q.18 A rod of weight w is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at a distance x from A.

(A) the normal reaction at A is $\frac{wx}{d}$ (B) the normal reaction at A is $\frac{w(d-x)}{d}$

(C) the normal reaction at B is $\frac{wx}{d}$ (D) the normal reaction at B is $\frac{w(d-x)}{d}$

Q.19 Two spheres are rolling with same velocity (for their C. M.) their ratio of kinetic energy is 2 : 1 & radius ratio is 2 : 1, their mass ratio will be :

(A) 2 : 1 (B) 4 : 1 (C) 8 : 1 (D) $2\sqrt{2}$: 1

Q.20 Three identical thin rods each of mass m & length l are placed along x, y & z-axis respectively they are placed such that, one end of each rod is at origin 'O'. Then moment of inertia of this system about z-axis is

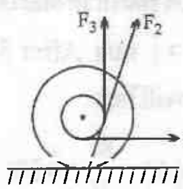
(A) $\frac{m\ell^2}{3}$ (B) $\frac{2m\ell^2}{3}$ (C) $m l^2$ (D) $\frac{m\ell^2}{4}$

Q.21 Two identical circular loops are moving with same kinetic energy one rolls & other slides. The ratio of their speed is :

(A) 2 : 3 (B) 2 : $\sqrt{2}$ (C) $\sqrt{2}$: 2 (D) $\sqrt{5}$: $\sqrt{3}$

Q.22 A paritcle falls freely near the surface of the earth. Consider a fixed point O (not vertically below the particle) on the ground.
(A) Angular momentum of the particle about O is increasing.
(B) Torque of the gravitational force on the particle about O is decreasing.
(C) The moment of inertia of the particle about O is decreasing.
(D) The angular velocity of the particle about O is increasing.

Q.23 A yo-yo is resting on a rough horizontal table. Forces F_1, F_2 and F_3 are applied separately as shown. The correct statement is
(A) when F_3 is applied the centre of mass will move to the right.
(B) when F_2 is applied the centre of mass will move to the left.
(C) when F_1 is applied the centre of mass will move to the right.
(D) when F_2 is applied the centre of mass will move to the right.

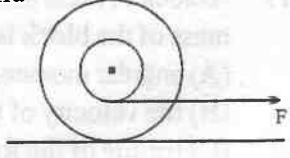


Q.24 A block with a square base measuring axa and height h, is placed on an inclined plane. The coefficient of friction is m. The angle of inclination (θ) of the plane is gradually increased. The block will

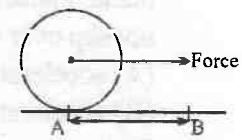
(A) topple before sliding if $\mu > \frac{a}{h}$ (B) topple before sliding if $\mu < \frac{a}{h}$

(C) slide before toppling if $\mu > \frac{a}{h}$ (D) slide before toppling if $\mu < \frac{a}{h}$

Q.25 Inner and outer radii of a spool are r and R respectively. A thread is wound over its inner surface and placed over a rough horizontal surface. Thread is pulled by a force F as shown in fig. then in case of pure rolling
(A) Thread unwinds, spool rotates anticlockwise and friction act leftwards
(B) Thread winds, spool rotates clockwise and friction acts leftwards
(C) Thread winds, spool moves to the right and friction act rightwards
(D) Thread winds, spool moves to the right and friction does not come into existence.



Q.26 A disc of circumference s is at rest at a point A on a horizontal surface when a constant horizontal force begins to act on its centre. Between A and B there is sufficient friction to prevent slipping, and the surface is smooth to the right of B. AB = s. The disc moves from A to B in time T. To the right of B,



(A) the angular acceleration of the disc will disappear, linear acceleration will remain unchanged
(B) linear acceleration of the disc will increase
(C) the disc will make one rotation in time T/2
(D) the disc will cover a distance greater than s in further time T.

Q.27 A weightless rod is acted on by upward parallel forces of 2N and 4N ends A and B respectively. The total length of the rod AB = 3m. To keep the rod in equilibrium a force of 6N should act in the following manner:
(A) Downwards at any point between A and B.
(B) Downwards at mid point of AB.
(C) Downwards at a point C such that AC = 1m.
(D) Downwards at a point D such that BD = 1m.

Q.28 A wheel of radius r rolling on a straight line, the velocity of its centre being v. At a certain instant the point of contact of the wheel with the grounds is M and N is the highest point on the wheel (diametrically opposite to M). The incorrect statement is:
(A) The velocity of any point P of the wheel is proportional to MP.
(B) Points of the wheel moving with velocity greater than v form a larger area of the wheel than points moving with velocity less than v.
(C) The point of contact M is instantaneously at rest.
(D) The velocities of any two parts of the wheel which are equidistant from centre are equal.

Q.29 A small object is attached to a light string which passes through a hollow tube. The tube is held by one hand and the string by the other. The object is stet into rotation in a circle of radius r_1. The string is then pulled down, shortening the radius of the circle to r_2. The ratio of the new kinetic energy to original kinetic energy is

(A) $\frac{r_1}{r_2}$ (B) 1 (C) $\left(\frac{r_1}{r_2}\right)^2$ (D) $\left(\frac{r_2}{r_1}\right)^2$

Q.30 Consider a sphere of mass 'm' radius 'R' doing pure rolling motion on a rough surface having velocity $\vec{v}_0$ as shown in the Fig. It makes an elastic impact with the smooth wall and moves back and starts pure rolling after some time again.
(A) Change in angular momentum about 'O' in the entire motion equals $2mv_0R$ in magnitude.
(B) Moment of impulse provided by the wall during impact about O equals $2mv_0R$ in magnitude.

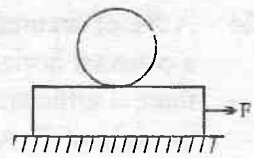
(C) Final velocity of ball will be $\frac{3}{7}\vec{v}_0$

(D) Final velocity of ball will be $-\frac{3}{7}\vec{v}_0$

Q.31 Two rods of equal mass m and length l lie along the x axis and y axis with their centres origin. What isthemoment finertia of both about the line x=y :

(A) $\frac{ml^2}{3}$ (B) $\frac{ml^2}{4}$ (C) $\frac{ml^2}{12}$ (D) $\frac{ml^2}{6}$

Q.32 A plank with a uniform sphere placed on it, rests on a smooth horizontal plane. Plank is pulled to right by a constant force F. If the sphere does not slip over the plank.



(A) acceleration of centre of sphere is less than that of the plank
(B) acceleration of centre of sphere is greater than the plank because friction acts rightward on the sphere
(C) acceleration of the centre of sphere may be towards left.
(D) acceleration of the centre of sphere relative to plank may be greater than that of the plank relative to floor.

Q.33 A hollow sphere of radius R and mass M is fully filled with water of mass m. It is rolled down a horizontal plane such that its centre of mass moves with a velocity v. If it purely rolls

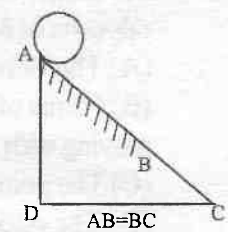
(A) Kinetic energy of the sphere is $\frac{5}{6}mv^2$

(B) Kinetic energy of the sphere is $\frac{4}{5}mv^2$

(C) Angular momentum of the sphere about a fixed point on ground is $\frac{8}{3}mvR$

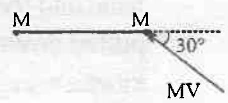
(D) Angular momentum of the sphere about a fixed point on ground is $\frac{14}{5}mvR$

Q.34 Portion AB of the wedge shown in figure is rough and BC is smooth. A solid cylinder rolls without slipping from A to B. The ratio of translational kinetic energy to rotational kinetic energy, when the cylinder reaches point C is :



(A) 3/4 (B) 5
(C) 7/5 (D) 8/3

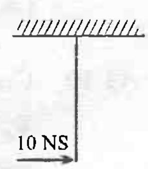
Q.35 Two equal masses each of mass M are joined by a massless rod of length L. Now an impulse MV is given to the mass M making an angle of 30° with the length of the rod. The angular veloctiy of the rod just after imparting the impulse is



(A) $\frac{v}{L}$ (B) $\frac{2v}{L}$

(C) $\frac{v}{2L}$ (D) none of these.

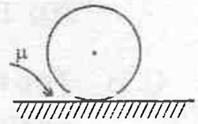
Q.36 A thin uniform straight rod of mass 2 kg and length 1 m is free to rotate about its upper end when at rest. It receives an impulsive blow of 10 Ns at its lowest point, normal to its length as shown in figure. The kinetic energy of rod just after impact is



(A) 75 J (B) 100 J (C) 200 J (D) none

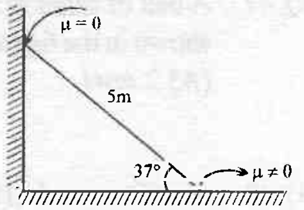
Q.37 A man, sitting firmly over a rotating stool has his arms streched. If he folds his arms, the work done by the man is
(A) zero (B) positive
(C) negative (D) may be positive or negative.

Q.38 A disc of radius r is rotating about its centre with an angular speed ω_0. It is gently placed on a rough horizontal surface. After what time it will be in pure rolling ?



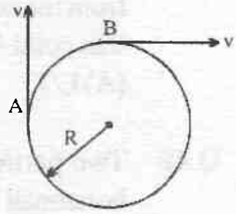
(A) $\frac{\omega_0 r}{2\mu g}$ (B) $\frac{\omega_0 r}{3\mu g}$ (C) $\frac{\omega_0 r}{\mu g}$ (D) $\frac{3\,\omega_0 r}{2\,\mu g}$

Q.39 A 5 m long pole of 3 kg mass is placed against a smooth vertical well as shown in the figure. Under equilibrium condition, if the pole makes an angle of 37° with the horizontal, the frictional force between the pole and horizontal surface is



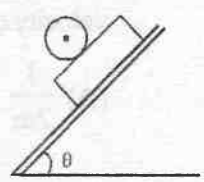
(A) 20 N (B) 30 N
(C) 20 μN (D) 30 μN

Q.40 Two points of a rigid body are moving as shown. The angular velocity of the body is:



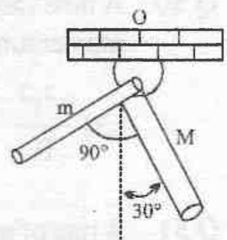
(A) $\frac{\upsilon}{2R}$ (B) $\frac{\upsilon}{R}$ (C) $\frac{2\upsilon}{R}$ (D) $\frac{2\upsilon}{3R}$

Q.41 A plank of mass M is placed over smooth inclined plane and a sphere is also placed over the plank. Friction is sufficient between sphere and plank. If plank and sphere are released from rest, the frictional force on sphere is:



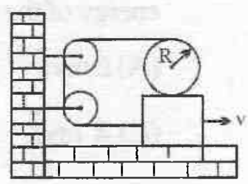
(A) up the plane (B) down the plane (C) horizontal (D) zero

Q.42 Two uniform rods of equal length but different masses are rigidly joined to form an L-shaped body, which is then pivoted as shown. If in equilibrium the body is in the shown configuration, ratio M/m will be:



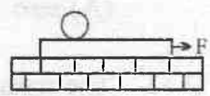
(A) 2 (B) 3 (C) $\sqrt{2}$ (D) $\sqrt{3}$

Q.43 In the figure shown, the plank is being pulled to the right with a constant speed v. If the cylinder does not slip then:



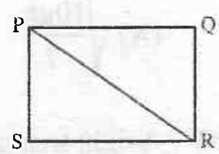
(A) the speed of the centre of mass of the cylinder is 2v.
(B) the speed of the centre of mass of the cylinder is zero.
(C) the angular velocity of the cylinder is v/R.
(D) the angular velocity of the cylinder is zero.

Q.44 A plank with a uniform sphere placed on it rests on a smooth horizontal plane. Plank is pulled to right by a constant force F. If sphere does not slip over the plank. Which of the following is incorrect.



(A) Acceleration of the centre of sphere is less than that of the plank.
(B) Work done by friction acting on the sphere is equal to its total kinetic energy.
(C) Total kinetic energy of the system is equal to work done by the force F
(D) None of the above

Q.45 Moment of inertia of a rectangular plate about an axis passing through P and perpendicular to the plate is I. Then moment of PQR about an axis perpendicular to the plane of the plate:

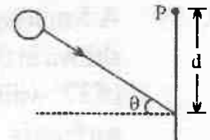


(A) about P = I/2 (B) about R = I/2
(C) about P > I/2 (D) about R > I/2

Q.46 A rod of length l is given two velocities v_1 and v_2 in opposite directions at its two ends at right angles to the length. The distance of the instantaneous axis of rotation from v_1 is:

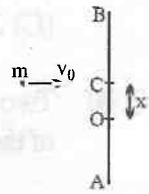
(A) zero (B) $\frac{v_1}{v_1 + v_2} l$ (C) $\frac{v_1 l}{v_1 + v_2}$ (D) $l/2$

Q.47 A ball of mass m moving with velocity v, collide with the wall elastically as shown in the figure. After impact the change in angular momentum about P is:



(A) 2 *mvd* (B) 2 *mvd* cosθ (C) 2 *mvd* sin θ (D) zero

Q.48 A uniform rod AB of length L and mass M is lying on a smooth table. A small particle of mass m strike the rod with a velocity v_0 at point C at a distance x from the centre O. The particle comes to rest after collision. The value of x, so that point A of the rod remains ststionary just after collision is:

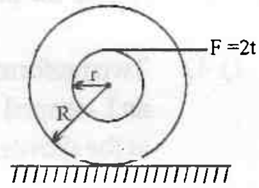


(A) L/3 (B) L/6 (C) L/4 (D) L/12

Q.49 Two particles of equal mass m at A and B are connected by a rigid light rod AB lying on a smooth horizontal table. An impulse J is applied at A in the plane of the table and perpendicular at AB. Then the velocity of particle at A is:

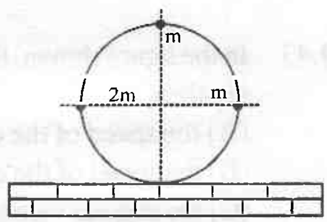
(A) $\frac{J}{2m}$ (B) $\frac{J}{m}$ (C) $\frac{2J}{m}$ (D) zero

Q.50 A time varying force F = 2t is applied on a spool as shown in figure. The angular momentum of the spool at time t about bottommost point is:



(A) $\frac{r^2t^2}{R}$ (B) $\frac{(R+r)^2}{r}t^2$ (C) $(R+r)t^2$ (D) data is insufficient

Q.51 A ring of mass m and radius R has three particles attached to the ring as shown in the figure. The centre of the ring has a speed v_0. The kinetic energy of the system is: (Slipping is absent)



(A) $6\,mv_0^2$ (B) $12\,mv_0^2$

(C) $4\,mv_0^2$ (D) $8\,mv_0^2$

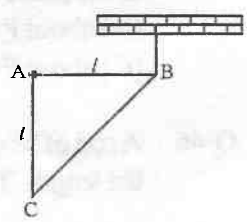
Q.52 A particle of mass 2 kg located at the position $(\hat{i}+\hat{j})$ m has a velocity $2(+\hat{i}-\hat{j}+\hat{k})$ m/s. Its angular momentum about z-axis in kg-m²/s is:

(A) zero (B) +8 (C) 12 (D) –8

Q.53 The linear speed of a uniform spherical shell after rolling down an inclined plane of vertical height h from rest, is:

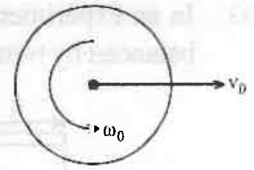
(A) $\sqrt{\frac{10gh}{7}}$ (B) $\sqrt{\frac{4gh}{5}}$ (C) $\sqrt{\frac{6gh}{5}}$ (D) $\sqrt{2gh}$

Q.54 A right triangular plate ABC of mass m is free to rotate in the vertical plane about a fixed horizontal axis through A. It is supported by a string such that the side AB is horizontal. The reaction at the support A is:



(A) $\frac{mg}{3}$ (B) $\frac{2mg}{3}$ (C) $\frac{mg}{2}$ (D) mg

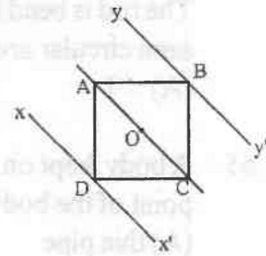
Q.55 A uniform sphere of radius R is placed on a rough horizontal surface and given a linear velocity v_0 angular velocity ω_0 as shown. The sphere comes to rest after moving some distance to the right. It follows that:



(A) $v_0 = \omega_0 R$ (B) $2v_0 = 5\omega_0 R$
(C) $5v_0 = 2\omega_0 R$ (D) $2v_0 = \omega_0 R$

Q.56 A particle is moving in a circular orbit of radius r_1 with an angular velocity ω_1. It jumps to another circular orbit of radius r_2 and attains an angular velocity ω_2. If $r_2 = 0.5\ r_1$ and assuming that no external torque is applied to the system, then the angular velocity ω_2, is given by :
(A) $\omega_2 = 4\ \omega_1$ (B) $\omega_2 = 3\ \omega_1$ (C) $\omega_2 = 2\ \omega_1$ (D) $\omega_2 = \omega_1$

Q.57 Let I_1, I_2 and I_3 be the moment of inertia of a uniform square plate about axes AOC, xDx' and yBy' respectively as shown in the figure. The moments of inertia of the plate $I_1 : I_2 : I_3$ are in the ratio.

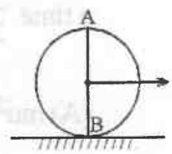


(A) $1 : \frac{1}{7} : \frac{1}{7}$ (B) $1 : \frac{12}{7} : \frac{12}{7}$

(C) $1 : \frac{7}{12} : \frac{7}{12}$ (D) $1 : 7 : 7$

Q.58 A solid uniform disk of mass m rolls without slipping down a fixed inclined plane with an acceleration a. The frictional force on the disk due to surface of the plane is :
(A) 2 ma (B) 3/2 ma (C) ma (D) 1/2 ma

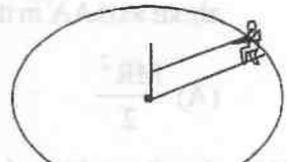
Q.59 A uniform solid disc is rolling on a horizontal surface. At a certain instant B is the point of contact and A is at height 2R from ground, where R is radius of disc.



(A) The magnitude of the angular momentum of the disc about B is thrice that about A.
(B) The angular momentum of the disc about A is anticlockwise.
(C) The angular momentum of the disc about B is clockwise
(D) The angular momentum of the disc about A is equal to that about B.

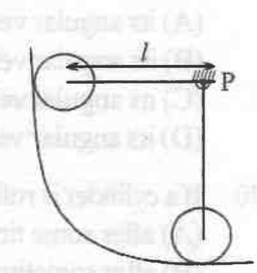
Q.60 If a person sitting on a rotating stool with his hands outstretched, suddenly lowers his hands, then his
(A) Kinetic energy will decrease (B) Moment of inertia will decrease
(C) Angular momentum will increase (D) Angular velocity will remain constant

Q.61 A man is sitting in a smooth groove on a horizontal circular table at the edge by holding a rope joined to the centre. The moment of inertia of table is I. Mass of man = M. Man now pulls the rope so that he comes to the centre. The angular velocity of the table :



(A) must increase (B) may increase
(C) must decrease (D) may decrease

Q.62 A sphere of mass M and radius R is attached by a light rod of length l to a point P. The sphere rolls without slipping on a circular track as shown. It is released from the horizontal position. the angular momentum of the system about P when the rod becomes vertical is :



(A) $M\sqrt{\frac{10}{7}gl}\ [l + R]$ (B) $M\sqrt{\frac{10}{7}gl}\left[l + \frac{2}{5}R\right]$

(C) $M\sqrt{\frac{10}{7}gl}\left[l + \frac{7}{5}R\right]$ (D) none of the above

Q.63 In an experiment with a beam balance on unknown mass m is balanced by two known mass m is balanced by two known masses of 16 kg and 4 kg as shown in figure.



The value of the unknown mass m is
(A) 10 kg (B) 6 kg (C) 8 kg (D) 12 kg

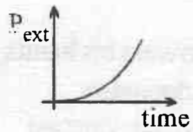
Q.64 A thin uniform rod of mass M and length L has its moment of inertia I_1 about its perpendicular bisector. The rod is bend in the form of a semicircular arc. Now its moment of inertia through the centre of the semi circular arc and perpendicular to its plane is I_2. The ratio of $I_1 : I_2$ will be ______
(A) < 1 (B) > 1 (C) = 1 (D) can't be said

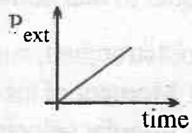
Q.65 A body kept on a smooth horizontal surface is pulled by a constant horizontal force applied at the top point of the body. If the body rolls purely on the surface, its shape can be :
(A) thin pipe (B) uniform cylinder (C) uniform sphere (D) thin spherical shell

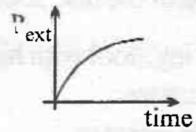
Q.66 A particle of mass m is projected with a velocity u making an angle 45° with the horizontal. The magnitude of the torque due to weight of the projectile, when the particle is at its maximum height, about a point at a time $\frac{u}{2\sqrt{2}g}$ on the trajectory is :

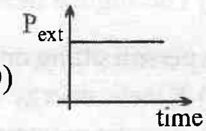
(A) mu^2 (B) $\frac{3}{4}mu^2$ (C) $\frac{1}{4}mu^2$ (D) $\frac{1}{2}mu^2$

Q.67 A rod is hinged at its centre and rotated by applying a constant torque starting from rest. The power developed by the external torque as a function of time is :

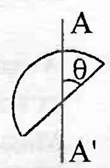
(A) 

(B) 

(C) 

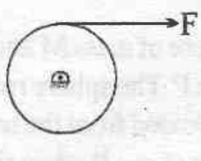
(D) 

Q.68 The moment of inertia of semicircular plate of radius R and mass M about axis AA' in its plane passing through its centre is



(A) $\frac{MR^2}{2}$ (B) $\frac{MR^2}{4}\cos^2\theta$ (C) $\frac{MR^2}{2}\sin^2\theta$ (D) $\frac{MR^2}{4}$

Q.69 A pulley is hinged at the centre and a massless thread is wrapped around it. The thread is pulled with a constant force F starting from rest. As the time increases,

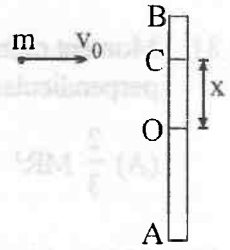


(A) its angular velocity increases, but force on hinge remains constant
(B) its angular velocity remains same, but force on hinge increases
(C) its angular velocity increases and force on hinge increases
(D) its angular velocity remains same and force on hinge is constant

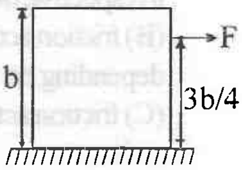
Q.70 If a cylinder is rolling down the incline with sliding.
(A) after some time it may start pure rolling
(B) after sometime it will start pure rolling
(C) it may be possible that it will never start pure rolling
(D) none of these

Q.71 A horizontal force F = mg/3 is applied on the upper surface of a uniform cube of mass 'm' and side 'a' which is resting on a rough horizontal surface having $\mu_S = 1/2$. The distance between lines of action of 'mg' and normal reaction 'N' is :
(A) a/2 (B) a/3 (C) a/4 (D) None

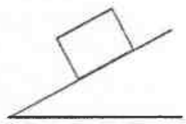
Q.72 A uniform rod AB of length L and mass M is lying on a smooth table. A small particle of mass *m* strike the rod with a velocity v_0 at point C a distance x from the centre O. The particle comes to rest after collision. The value of x, so that point A of the rod remains stationary just after collision, is :
(A) L/3 (B) L/6
(C) L/4 (D) L/12



Q.73 A uniform cube of side 'b' and mass M rest on a rough horizontal table. A horizontal force F is applied normal to one of the face at a point, at a height 3b/4 above the base. What should be the coefficient of friction (μ) between cube and table so that is will tip about an edge before it starts slipping?
(A) $\mu > \frac{2}{3}$ (B) $\mu > \frac{1}{3}$ (C) $\mu > \frac{3}{2}$ (D) none

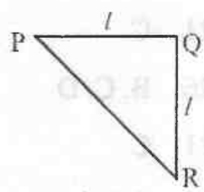


Q.74 A homogeneous cubical brick lies motionless on a rough inclined surface. The half of the brick which applies greater pressure on the plane is :
(A) left half (B) right half
(C) both applies equal pressure (D) the answer depend upon coefficient of friction



Q.75 A body weighs 6 gms when placed in one pan and 24 gms when placed on the other pan of a false balance. If the beam is horizontal when both the pans are empty, the true weight of the body is :
(A) 13 gm (B) 12 gm (C) 15.5 gm (D) 15 gm

Q.76 In the triangular sheet given PQ = QR = l. If M is the mass of the sheet. What is the moment of inertial about PR



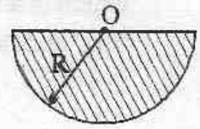
(A) $\frac{Ml^2}{24}$ (B) $\frac{Ml^2}{12}$ (C) $\frac{Ml^2}{6}$ (D) $\frac{Ml^2}{18}$

Q.77 A slender uniform rod of length ℓ is balanced vertically at a point P on a horizontal surface having some friction. If the top of the rod is displaced slightly to the right, the position of its centre of mass at the time when the rod becomes horizontal :
(A) lies at some point to the right of P (B) lies at some point to the left of P
(C) must be $\ell/2$ to the right of P (D) lies at P

Q.78 A solid sphere with a velocity (of centre of mass) v and angular velocity ω is gently placed on a rough horizontal surface. The frictional force on the sphere:
(A) must be forward (in direction of v) (B) must be backward (opposite to v)
(C) cannot be zero (D) none of the above

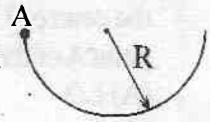
Q.79 A ball is attached to an end of a light inextensible string, the other end of which is fixed at the origin. The ball moves in vertical x-y plane where x is along horizontal and y along vertical. At the top of its trajectory, it's velocity is $\sqrt{5}\,\hat{i}$ m/s. The angular velocity vector when ball is at the bottom of the trajectory is : [length of string = 0.5 m]
(A) $10\,\hat{k}$ rad/s (B) $\sqrt{5}\,\hat{k}$ rad/s (C) $5\,\hat{j}$ rad/s (D) $-10\,\hat{k}$ rad/s

Q.80 Moment of inertia of a thin semicircular disc (mass = M & radius = R) about an axis through point O and perpendicular to plane of disc, is given by :



(A) $\frac{1}{4}$ MR^2 (B) $\frac{1}{2}$ MR^2 (C) $\frac{1}{8}$ MR^2 (D) MR^2

Q.81 Moment of inertia of a semicircular ring of radius R and mass M ; about an axis passing through A and perpendicular to the plane of the paper is



(A) $\frac{2}{3}$ MR^2 (B) MR^2 (C) $\frac{5}{\pi}$ MR^2 (D) 2MR^2

Q.82 Which of the following statements are correct.
(A) friction acting on a cylinder without sliding on an inclined surface is always upward along the incline irrespective of any external force acting on it.
(B) friction acting on a cylinder without sliding on an inclined surface is may be upward may be downwards depending on the external force acting on it.
(C) friction acting on a cylinder rolling without sliding may be zero depending on the external force acting on it.
(D) nothing can be said exactly about it as it depends on the friction coefficient on inclined plane.

ANSWER KEY

Q.1 B	Q.2 D	Q.3 B	Q.4 D	Q.5 B
Q.6 D	Q.7 B	Q.8 B	Q.9 C	Q.10 A
Q.11 C	Q.12 A	Q.13 A, B, C, D	Q.14 B	Q.15 C
Q.16 D	Q.17 A, B, D	Q.18 B, C	Q.19 A	Q.20 B
Q.21 C	Q.22 A, C, D	Q.23 C	Q.24 A, D	Q.25 B
Q.26 B, C, D	Q.27 D	Q.28 D	Q.29 C	Q.30 A, B, D
Q.31 C	Q.32 A	Q.33 C	Q.34 B	Q.35 C
Q.36 A	Q.37 B	Q.38 B	Q.39 A	Q.40 B
Q.41 D	Q.42 D	Q.43 B, C	Q.44 D	Q.45 C
Q.46 B	Q.47 B	Q.48 B	Q.49 B	Q.50 C
Q.51 A	Q.52 D	Q.53 C	Q.54 B	Q.55 C
Q.56 A	Q.57 D	Q.58 D	Q.59 A, B, C	Q.60 B
Q.61 B	Q.62 D	Q.63 C	Q.64 A	Q.65 A
Q.66 C	Q.67 B	Q.68 D	Q.69 A	Q.70 A, C
Q.71 B	Q.72 B	Q.73 A	Q.74 A	Q.75 B
Q.76 B	Q.77 A	Q.78 D	Q.79 D	Q.80 B
Q.81 D	Q.82 B, C			

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (P,Q,R,S & J)

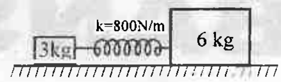
SIMPLE HARMONIC MOTION

CONTENTS

EXERCISE–I

Q.1 A body is in SHM with period T when oscillated from a freely suspended spring. If this spring is cut in two parts of length ratio 1 : 3 & again oscillated from the two parts separately, then find the periods are T_1 & T_2 then T_1/T_2.

Q.2 The system shown in the figure can move on a smooth surface. The spring is initially compressed by 6 cm and then released. Find



(a) time period of sum

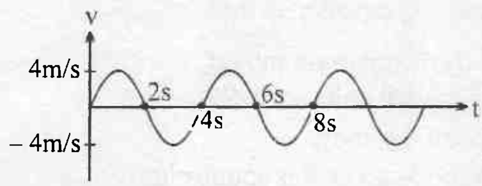
(b) amplitude of 3 kg block

(c) maximum momentum of 6 kg block

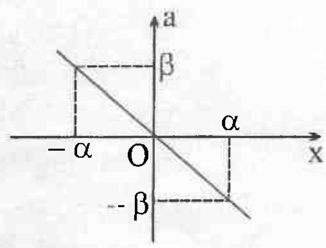
Q.3 A body undergoing SHM about the origin has its equation is given by $x = 0.2 \cos 5\pi t$. Find its average speed from t = 0 to t = 0.7 sec.

Q.4 A bead of mass m is fixed at the centre of the string of length L fixed at both the ends in a gravity free space. The tension in the string is T. If the bead is displaced slightly from it's position in a direction perpendicular to the string then find the period of small oscillation about the mean position.

Q.5 If velocity of a particle moving along a straight line changes sinusoidally with time as shown in the given graph, its average velocity over time interval t=0 to t=2(2n – 1) seconds, n being any +ve integer. will be

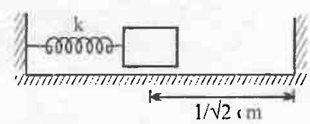


Q.6 The acceleration-displacement (a – x) graph of a particle executing simple harmonic motion is shown in the figure. Find the frequency of oscillation.



Q.7 Two particles A and B execute SHM along the same line with the same amplitude a, same frequency and same equilibrium position O. If the phase difference between them is $\phi = 2 \sin^{-1}(0.9)$, then find the maximum distance between the two.

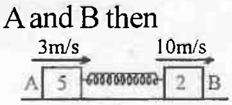
Q.8 A block of mass 0.9 kg attached to a spring of force constant K is lying on a frictionless floor as shown in the figure. The spring is compressed to $\sqrt{2}$ cm and the block is at a distance $1/\sqrt{2}$ cm from the wall. When the block is released, it makes elastic collision with the wall and its period of motion is 0.2 sec. Find the approximate value of K.



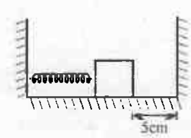
Q.9 Two blocks A (5kg) and B(2kg) attached to the ends of a spring constant 1120N/m are placed on a smooth horizontal plane with the spring undeformed. Simultaneously velocities of 3m/s and 10m/s along the line of the spring in the same direction are imparted to A and B then

(a) find the maximum extension of the spring.

(b) when does the first maximum compression occurs after start.



Q.10 A block of mass 100gm attached to a spring of spring constant 100N/m is lying on a frcitionless floor as shown. The block is moved to compress the spring by 10cm and then released. If the collisions with the wall in front are elastic then find the time period of the motion.

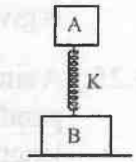


Q.11 A particle is performing SHM with accleration $a = 8\pi^2 - 4\pi^2 x$ where x is coordinate of the particle w.r.t. the origin. The parameters are in S.I. units. The particle is at rest at $x = -2$ at $t = 0$. Find coordinate of the particle w.r.t. origin at any time.

Q.12 Two identical rods each of mass m and length L, are rigidly joined and then suspended in a vertical plane so as to oscillate freely about an axis normal to the plane of paper passing through 'S' (point of supension). Find the time period of such small oscillations.



Q.13 A body A of mass $m_1 = 1$ kg and a body B of mass $m_2 = 4$ kg are attached to the ends of a spring. The body A performs vertical simple harmonic oscillations of amplitude a = 1.5 cm and angular frequency $\omega = 25$ rad/s. Neglecting the mass of the spring determine the maximum and minimum values of force the system exerts on the surface on which it rests. [Take $g = 10\ m/s^2$]



Q.14 Consider a fixed ring shaped uniform body of linear mass density ρ and radius R. A particle at the centre of ring is displaced along the axis by a small distance, show that the particle will execute SHM under gravitation of ring & find its time period neglecting other forces.

Q.15 Assume that a tunnel is dug across the earth (radius = R) passing through its centre. Find the time a particle takes to reach centre of earth if it is projected into the tunnel from surface of earth with speed needed for it to escape the gravitational field of earth.

Q.16 A force $f = -10x + 2$ acts on a particle of mass 0.1 kg, where 'k' is in m and F in newton. If it is released from rest at $x = -2$ m, find :
(a) amplitude ; (b) time period ; (c) equation of motion.

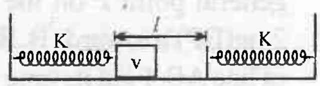
Q.17 Potential Energy (U) of a body of unit mass moving in a one-dimension conservative force field is given by, $U = (x^2 - 4x + 3)$. All units are in S.I.
(i) Find the equilibrium position of the body.
(ii) Show that oscillations of the body about this equilibrium position is simple harmonic motion & find its time period.
(iii) Find the amplitude of oscillations if speed of the body at equilibrium position is $2\sqrt{6}$ m/s.

Q.18 A spring of force constant k is cut into two parts whose lengths are in the ratio 1 : 2. The two parts are now connected in parallel and a block of mass m is suspended at the end of the combined spring. Find the period of oscillation performed by the block.

Q.19(a) Find the time period of oscillations of a torsional pendulum, if the torsional constant of the wire is $K = 10\pi^2$ J/rad. The moment of inertia of rigid body is 10 kg m^2 about the axis of rotation.

(b) A simple pendulum of length $l = 0.5$ m is hanging from ceiling of a car. The car is kept on a horizontal plane. The car starts accelerating on the horizontal road with acceleration of 5 m/s^2. Find the time period of oscillations of the pendulum for small amplitudes about the mean position.

Q.20 Two springs of same spring constants are arranged as shown in figure. A block of mass m strikes one of the spring with velocity v. Find the period of oscillation of the block.



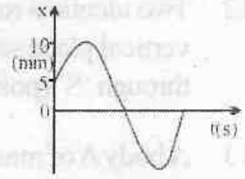
Q.21 The resulting amplitude A' and the phase of the vibrations δ

$$S = A\cos(wt) + \frac{A}{2}\cos\left(\omega t + \frac{\pi}{2}\right) + \frac{A}{4}\cos(\omega t + \pi) + \frac{A}{8}\cos\left(\omega t + \frac{3\pi}{2}\right) = A'\cos(\omega t + \delta)$$ are ______ and ______ respectively.

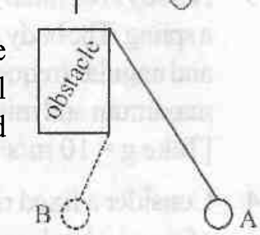
Q.22 A body is executing SHM under the action of force whose maximum magnitude is 50N. Find the magnitude of force acting on the particle at the time when its energy is half kinetic and half potential.

Q.23 The motion of a particle is described by $x = 30\sin(\pi t + \pi/6)$, where x is in cm and t in sec. Potential energy of the particle is twice of kinetic energy for the first time after t = 0 when the particle is at position ______ after ______ time.

Q.24 The figure shows the displacement - time graph of a particle executing SHM. If the time period of oscillation is 2s, then the equation of motion is given by x = ________.



Q.25 A simple pendulum has a time period T = 2 sec when it swings freely. The pendulum is hung as shown in figure, so that only one-fourth of its total length is free to swing to the left of obstacle. It is displaced to position A and released. How long does it take to swing to extreme displacement B and return to A? Assume that dispalcement angle is always small.



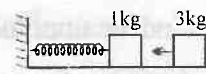
EXERCISE–II

Q.1 A point particle of mass 0.1kg is executing SHM with amplitude of 0.1m. When the particle passes through the mean position, its K.E. is 8×10^{-3}J. Obtain the equation of motion of this particle if the initial phase of oscillation is 45°.

Q.2 The particle executing SHM in a straight line has velocities 8 m/s, 7 m/s, 4 m/s at three points distant one metre from each other. What will be the maximum velocity of the particle?

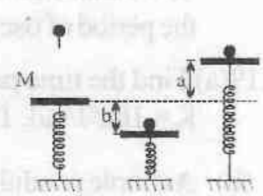
Q.3 At the moment t = 0 a particle starts moving rectilinearly so that it's velocity varies as v = 25cosπt cm/s where t is expressed in seconds. Find the distance that this particle covers during t = 2.80 s after the start.

Q.4 One end of an ideal spring is fixed to a wall at origin O and the axis of spring is parallel to x-axis. A block of mass m = 1 kg is attached to free end of the spring and it is performing SHM. Equation of position of block in coordinate system shown is x = 10 + 3sin10t, t is in second and x in cm. Another block of mass M = 3kg, moving towards the origin with velocity 30cm/c collides with the block performing SHM at t = 0 and gets struck to it, calculate :



(i) new amplitude of oscillations.
(ii) new equation for position of the combined body.
(iii) loss of energy during collision. Neglect friction.

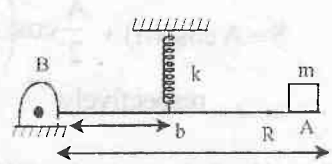
Q.5 A mass M is in static equilibrium on a massless vertical spring as shown in the figure. A ball of mass m dropped from certain height sticks to the mass M after colliding with it. The oscillations they perform reach to height 'a' above the original level of scales & depth 'b' below it.



(a) Find the constant of force of the spring.; (b) Find the oscillation frequency.
(c) What is the height above the initial level from which the mass m was dropped ?

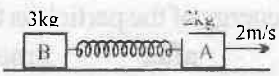
Q.6 A particle of mass m moves on a horizontal smooth line AB of length a such that when particle is at any general point P on the line two forces act on it. A force mg(AP)/a towards A and another force 2mg(BP)/a towards B. Show that particle performs SHM on the line when left from rest from mid-point of line AB. Find its time period and amplitude. Find the minimum distance of the particle from B during the motion. If the force acting towards A stops acting when the particle is nearest to B then find the velocity with which it crosses point B.

Q.7 The rod AB of mass M is attached as shown to a spring of constant K. A small block of mass m is placed on the rod at its free end A.



(a) if end A is moved down through a small distance d and released, determine the period of vibration.
(b) determine the largest allowable value of d if the block m is to remain at all times in contact with the rod.

Q.8 Two blocks A(2kg) and B(3kg) rest up on a smooth horizontal surface are connected by a spring of stiffness 120 N/m. Initially the spring is undeformed. A is imparted a velocity of 2m/s along the line of the spring away from B. Find the displacement of A t seconds later.

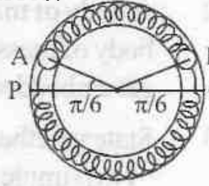


Q.9 Two identical balls A and B each of mass 0.1 kg are attached to two identical massless springs. The spring mass system is constrained to move inside a rigid smooth pipe in the form of a circle as in fig. The pipe is fixed in a horizontal plane. The centres of the ball can move in a circle of radius 0.06m. Each spring has a natural length 0.06π m and force constant 0.1N/m. Initially both the balls are displaced by an angle of $\theta = \pi/6$ radian with respect to diameter PQ of the circle and released from rest

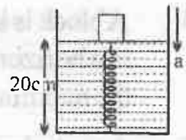
(a) Calculate the frequency of oscillation of the ball B.

(b) What is the total energy of the system.

(c) Find the speed of the ball A when A and B are at the two ends of the diameter PQ.



Q.10 A rectangular tank having base 15cm x 20cm is filled with water ($\rho = 1000 kg/m^3$) upto 20cm height. One end of an ideal spring of natural length $l_0 = 20$cm and force constant k = 280N/m is fixed to the bottom of a tank so that spring remains vertical. This system is in an elevator moving downwards with acceleration $a = 2m/s^2$. A cubical block of side $l = 10$cm and mass m = 2kg gently placed over the spring and released gradually, (as shown)

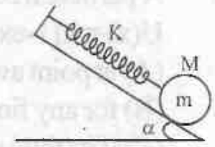


(i) Calculate compression of the spring in equilibrium position.

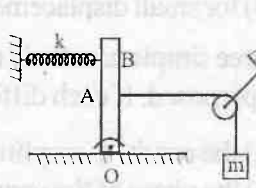
(ii) If block is slightly down from equilibrium position and released calculate the frequency of its vertical oscillations.

Q.11 An ideal gas is enclosed in a vertical cylindrical container and supports a freely moving piston of mass m. The piston and the cylinder have equal cross-sectional area A, atmospheric pressure is P_0 and when the piston is in equilibrium position. Show that the piston executes SHM and find the frequency of oscillation (system is completely isolated from the surrounding). $\gamma = Cp/Cv$. Height of the gas in equilibrium position is h.

Q.12 Find the angular frequency of the small oscillations of the cylinder of mass M containing water of mass m. The spring has a constant K and cylinder executes pure rolling. What happens when the water in the cylinder freezes?



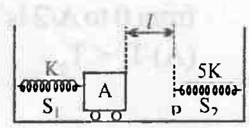
Q.13 A massless rod is hinged at O. A string carrying a mass *m* at one end is attached to point A on the rod so that OA = a. At another point B (OB= b) of the rod, a horizontal spring of force constant *k* is attached as shown. Find the period of small vertical oscillations of mass *m* around its equilibrium position. What can be the maximum amplitude of its oscillation so that its motion may remain simple harmonic.



Q.14 Being a punctual man, a lift operator hung an exact pendulum clock on the lift wall to know the end of the working day. The lift moves with an upwards and downwards accelaration during the same time (according to the stationary clock on the ground), the magnitudes of the accelarations remain unchanged. Will the operator finish his working day in time, or will he work more(less) than required

Q.15 Two elastic strings obeying hooks law each of unstretched length l, each has one end attached to a particle of mass m lying on smooth horizontal floor. The other ends of the string are attached at points A & B which are at a distance $3l$ apart. Each would be doubled in length by a tension 2 mg. The particle is held at rest at A and then released. Show that after released that particle first reaches B at time $\sqrt{\frac{\ell}{g}}\left[\frac{\pi\sqrt{2}}{3} + \sin^{-1}\sqrt{\frac{1}{7}}\right]$

Q.16 A body A of mass m is connected to a light spring s_1 of spring constant k. At the right of 'A' there is a second light spring s_2 of spring constant 5 k and having a massless vertical pan (P) attached to its free end as shown in the figure. Distance between the pan and the block when both the springs are in the relaxed position is l. Body A is moved by $3l$ distance to left from the configuration of static equilibrium and then released. What is the period of oscillation of the body? What is the maximum force experienced by the body A?



EXERCISE–III

Q.1 An object of mass 0.2 kg executes SHM along the x-axis with frequency of $(25/\pi)$ Hz. At the point $x = 0.04$m the object has KE 0.5 J and PE 0.4 J. The amplitude of oscillation is ______. [JEE' 94]

Q.2 A body of mass 1 kg is suspended from a weightless spring having force constant 600N/m. Another body of mass 0.5 kg moving vertically upwards hits the suspended body with a velocity of 3.0m/s and get embedded in it. Find the frequency of oscillations and amplitude of motion. [REE' 94]

Q.3 State whether true or false
"Two simple harmonic motions are represented by the equations
$x_1 = 5\sin[2\pi t + \pi/4]$ and $x_2 = 5\sqrt{2}\,(\sin 2\pi t + \cos 2\pi t)$ their amplitudes are in the ratio 1 : 2" [REE' 96]

Q.4 A block is kept on a horizontal table. The table is undergoing simple harmonic motion of frequency 3 Hz in a horizontal plane. The coefficient of static friction between block and the table surface is 0.72. Find the maximum amplitude of the table at which the block does not slip on the surface. [REE' 96]

Q.5 A particle of mass m is executing oscillations about the origin on the x-axis. Its potential energy is $V(x) = k|x|^3$ where k is a positive constant. If the amplitude of oscillations is a, then its time period T is
(A) proportional to $1/\sqrt{a}$ (B) independent of a
(C) proportional to $\sqrt{a}$ (D) proportional to $a^{3/2}$ [JEE' 98]

Q.6 A particle free to move along the x-axis has potential energy given by
$U(x) = k[1 - \exp(-x^2)]$ for $-\infty < x < +\infty$, where k is a positive constant of appropriate dimensions. Then
(A) at point away from the origin, the particle is in unstable equilibrium.
(B) for any finite nonzero value of x, there is a force directed away from the origin.
(C) if its total mechanical energy is k/2, it has its minimum kinetic energy at the origin.
(D) for small displacements from x = 0, the motion is simple harmonic. [JEE' 99]

Q.7 Three simple harmonic motions in the same direction having the same amplitude a and same period are superposed. If each differs in phase from the next by 45^0, then
(A) the resultant amplitude is $(1+\sqrt{2})$a
(B) the phase of the resultant motion relative to the first is 90^0.
(C) the energy associated with the resulting motion is $(3 + 2\sqrt{2})$ times the energy associated with any single motion.
(D) the resulting motion is not simple harmonic. [JEE' 99]

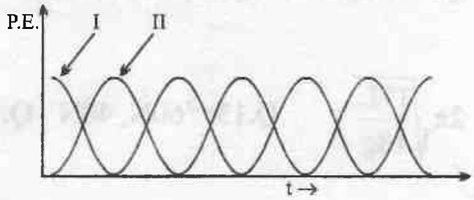
Q.8 The period of oscillation of simple pendulum of length L suspended from the roof of a vehicle which moves without friction down an inclined plane of inclination α is given by [JEE' 2000]
(A) $2\pi\sqrt{\frac{L}{g\cos\alpha}}$ (B) $2\pi\sqrt{\frac{L}{g\sin\alpha}}$ (C) $2\pi\sqrt{\frac{L}{g}}$ (D) $2\pi\sqrt{\frac{L}{g\tan\alpha}}$

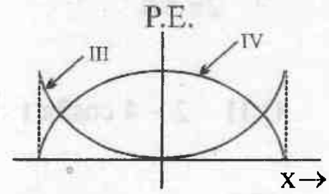
Q.9 A bob of mass M is attached to the lower end of a vertical string of length L and cross sectional area A. The Young's modulus of the material of the string is Y. If the bob executes SHM in the vertical direction, find the frequency of these oscillations. [REE' 2000]

Q.10 A particle executes simple harmonic motion between $x = -A$ and $x = +A$. The time taken for it to go from 0 to A/2 is T_1 and to go from A/2 to A is T_2. Then [JEE (Scr)' 2001]
(A) $T_1 < T_2$ (B) $T_1 > T_2$ (C) $T_1 = T_2$ (D) $T_1 = 2T_2$

Q.11 A diatomic molecule has atoms of masses m_1 and m_2. The potential energy of the molecule for the interatomic separation r is given by $V(r) = -A + B(r - r_0)^2$, where r_0 is the equilibrium separation, and A and B are positive constants. The atoms are compressed towards each other from their equilibrium positions and released. What is the vibrational frequency of the molecule? [REE' 2001]

Q.12 A particle is executing SHM according to $y = a \cos \omega t$. Then which of the graphs represents variations of potential energy : [JEE (Scr)' 2003]





(A) (I) & (III)
(B) (II) & (IV)
(C) (I) & (IV)
(D) (II) & (III)

Q.13 Two masses m_1 and m_2 connected by a light spring of natural length l_0 is compressed completely and tied by a string. This system while moving with a velocity v_0 along +ve x-axis pass through the origin at $t = 0$. At this position the string snaps. Position of mass m_1 at time t is given by the equation.

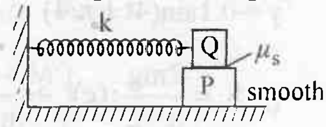
$x_1(t) = v_0 t - A(1 - \cos\omega t)$

Calculate :

(a) Position of the particle m_2 as a function of time.

(b) l_0 in terms of A. [JEE' 2003]

Q.14 A block P of mass m is placed on a frictionless horizontal surface. Another block Q of same mass is kept on P and connected to the wall with the help of a spring of spring constant k as shown in the figure. μ_s is the coefficient of friction between P and Q. The blocks move together performing SHM of amplitude A. The maximum value of the friction force between P and Q is



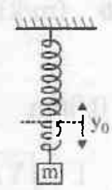
(A) kA
(B) $\frac{kA}{2}$
(C) zero
(D) $\mu_s mg$

[JEE' 2004]

Q.15 A simple pendulum has time period T_1. When the point of suspension moves vertically up according to the equation $y = kt^2$ where $k = 1\ m/s^2$ and 't' is time then the time period of the pendulum is T_2 then $\left(\frac{T_1}{T_2}\right)^2$ is [JEE' 2005 (Scr)]

(A) $\frac{5}{6}$
(B) $\frac{11}{10}$
(C*) $\frac{6}{5}$
(D) $\frac{5}{4}$

Q.16 A small body attached to one end of a vertically hanging spring is performing SHM about it's mean position with angular frequency ω and amplitude a. If at a height y* from the mean position the body gets detached from the spring, calculate the value of y* so that the height H attained by the mass is maximum. The body does not interact with the spring during it's subsequent motion after detachment. ($a\omega^2 > g$).



[JEE 2005]

ANSWER KEY

EXERCISE–I

Q.1 $1/\sqrt{3}$ **Q.2** (a) $\frac{\pi}{10}$ sec, (b) 4 cm, (c) 2.40 kg m/s. **Q.3** 2 m/s **Q.4** $T = \pi\sqrt{\frac{mL}{T}}$

Q.5 $\frac{8}{\pi(2n-1)}$ **Q.6** $\frac{1}{2\pi}\sqrt{\frac{\beta}{\alpha}}$ **Q.7** 1.8 a **Q.8** 100 Nm^{-1} **Q.9** (a) 25cm, (b) $3\pi/56$ seconds

Q.10 0.133 sec. **Q.11** $2 - 4\cos 2\pi t$ **Q.12** $2\pi\sqrt{\frac{17L}{18g}}$ **Q.13** 60N, 40N **Q.14** $\sqrt{\frac{2\pi R^2}{G\rho}}$

Q.15 $T = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)\sqrt{\frac{R_e}{g}}$ **Q.16** $\frac{11}{5}$ m, (b) $\frac{\pi}{5}$ sec., (c) $x = 0.2 - \frac{11}{5}\cos\omega t$

Q.17 (i) $x_0 = 2m$; (ii) $T = \sqrt{2}\ \pi$ sec.; (iii) $2\sqrt{3}$ **Q.18** $T=2\pi\sqrt{(2m/9k)}$

Q.19 (a) 2 sec, (b) $T = \frac{2}{5^{1/4}}$ sec **Q.20** $2\pi\sqrt{\frac{m}{K}} + \frac{2\ell}{v}$ **Q.21** $\frac{3\sqrt{5}\,A}{8}$, $\tan^{-1}\left(\frac{1}{2}\right)$ **Q.22** $25\sqrt{2}$ N

Q.23 $10\sqrt{6}$ cm, $\frac{1}{\pi}\sin^{-1}\left(\sqrt{\frac{2}{3}}\right) - \frac{1}{6}$ sec **Q.24** $x = 10\sin(\pi t + \pi/6)$ **Q.25** $\frac{3}{2}$ sec

EXERCISE–II

Q.1 $y = 0.1\sin(4t + \pi/4)$ **Q.2** $\sqrt{65}$ m/s **Q.3** $s = 0.4$ m **Q.4** 3cm, $x = 10 - 3\sin 5t$; $\Delta E = 0.135J$

Q.5 (a) $K = \frac{2mg}{b-a}$; (c) $\left(\frac{M+m}{m}\right)\frac{ab}{b-a}$, $\frac{1}{2\pi}\sqrt{\frac{2mg}{(b-a)(M+m)}}$

Q.6 $T = 2\pi\sqrt{a/3g}$, $A = a/6, a/6, 1/6\sqrt{2ag}$ **Q.7** $T = 2\pi\frac{R}{b}\sqrt{\frac{M+3m}{3K}}$, $d \le \frac{gR^2(M+3m)}{3Kb^2}$

Q.8 $0.8t + 0.12\sin 10t$ **Q.9** $f = \frac{1}{\pi}$; $E = 4\pi^2 \times 10^{-5}$J; $v = 2\pi\times10^{-2}$m/s **Q.10** $x = 4$cm. $f = \frac{5\sqrt{2}}{\pi}$

Q.11 $f = \frac{1}{2\pi}\sqrt{\frac{\gamma(P_0 + mg/A)A}{mh}}$ **Q.12** $\omega = \sqrt{\frac{K}{2M+m}}$; $\omega' = \sqrt{\frac{2K}{(4M+3m)}}$

Q.13 $(2\pi a/b)(m/k)^{1/2}$, a^2mg/b^2k **Q.14** works more

Q.16 $(m/k)^{1/2}[\pi+2\sin^{-1}(1/3)]+(m/6k)^{1/2}[\pi-2\sin^{-1}(1/7)]$; $F_{max} = 7kl$

EXERCISE–III

Q.1 0.06m **Q.2** $10/\pi$ Hz, 5cm **Q.3** T **Q.4** 2cm **Q.5** A **Q.6** D **Q.7** A, C **Q.8** A

Q.9 $\frac{1}{2\pi}\sqrt{\frac{YA}{ML}}$ **Q.10** A **Q.11** $2\pi\sqrt{\frac{m_1m_2}{2B(m_1+m_2)}}$ **Q.12** A

Q.13 (a) $x_2 = v_0t + \frac{m_1}{m_2}A(1-\cos\omega t)$, (b) $l_0 = \left(\frac{m_1}{m_2}+1\right)A$ **Q.14** B **Q.15** C **Q.16** $y^* = \frac{mg}{k} = \frac{g}{\omega^2} < a$

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007

XI (P,Q,R,S & J)

QUESTION BANK ON

SIMPLE HARMONIC MOTION

Time Limit : 2 Sitting Each of 90 minutes. duration approx.

Objective Question Bank On Simple Harmonic Motion

There are 53 questions in this question bank.

Q.1 Two particles are in SHM on same straight line with amplitude A and 2A and with same angular frequency ω. It is observed that when first particle is at a distance $A/\sqrt{2}$ from origin and going toward mean position, other particle is at extreme position on other side of mean position. Find phase difference between the two particles

(A) 45° (B) 90° (C) 135° (D) 180°

Q.2 A particle is executing SHM of amplitude A, about the mean position x = 0. Which of the following cannot be a possible phase difference between the positions of the particle at $x = +A/2$ and $x = -A/\sqrt{2}$.

(A) 75° (B) 165° (C) 135° (D) 195°

Q.3 Find the ratio of time periods of two identical springs if they are first joined in series & then in parallel & a mass m is suspended from them :

(A) 4 (B) 2 (C) 1 (D) 3

Q.4 A simple harmonic motion having an amplitude A and time period T is represented by the equation :
$y = 5\sin\pi(t+4)$ m
Then the values of A (in m) and T (in sec) are :

(A) A = 5; T = 2 (B) A = 10 ; T = 1 (C) A = 5 ; T = 1 (D) A = 10 ; T = 2

Q.5 A particle is subjected to two mutually perpendicular simple harmonic motions such that its x and y coordinates are given by

$$x = 2\sin\omega t \;;\; y = 2\sin\left(\omega t + \frac{\pi}{4}\right)$$

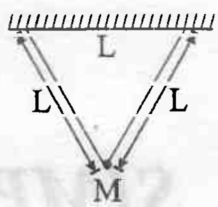
The path of the particle will be :

(A) an ellipse (B) a straight line (C) a parabola (D) a circle

Q.6 In an elevator, a spring clock of time period T_S (mass attached to a spring) and a pendulum clock of time period T_P are kept. If the elevator accelerates upwards

(A) T_S well as T_P increases (B) T_S remain same, T_P increases
(C) T_S remains same, T_P decreases (D) T_S as well as T_P decreases

Q.7 A man is swinging on a swing made of 2 ropes of equal length L and in direction perpendicular to the plane of paper. The time period of the small oscillations about the mean position is



(A) $2\pi\sqrt{\frac{L}{2g}}$ (B) $2\pi\sqrt{\frac{\sqrt{3}L}{2g}}$

(C) $2\pi\sqrt{\frac{L}{2\sqrt{3}g}}$ (D) $\pi\sqrt{\frac{L}{g}}$

Q.8 Two bodies P & Q of equal mass are suspended from two separate massless springs of force constants k_1 & k_2 respectively. If the maximum velocity of them are equal during their motion, the ratio of amplitude of P to Q is :

(A) $\frac{k_1}{k_2}$ (B) $\sqrt{\frac{k_2}{k_1}}$ (C) $\frac{k_2}{k_1}$ (D) $\sqrt{\frac{k_1}{k_2}}$

Q.9 The magnitude of the force acting on a particle of mass m during its motion in x-y plane according to the $x = a \sin \omega t$, $y = b \cos \omega t$, where a, b and ω are constants is

(A) $m\omega^2\sqrt{x^2+y^2}$ (B) $m\omega\sqrt{x^2+y^2}$ (C) $m\omega(x^2+y^2)$ (D) $m\omega^2(x+y)$

Q.10 Speed v of a particle moving along a straight line, when it is at a distance x from a fixed point on the line is given by $v^2 = 108 - 9x^2$ (all quantities in S.I. unit). Then

(A) The motion is uniformly accelerated along the straight line

(B) The magnitude of the acceleration at a distance 3 cm from the fixed point is 0.27 m/s^2.

(C) The motion is simple harmonic about $x = \sqrt{12}$ m.

(D) The maximum displacement from the fixed point is 4 cm.

Q.11 A particle performing SHM is found at its equilibrium at t = 1sec. and it is found to have a speed of 0.25 m/s at t = 2 sec. If the period of oscillation is 6 sec. Calculate amplitude of oscillation

(A) $\frac{3}{2\pi}$ m (B) $\frac{3}{4\pi}$ m (C) $\frac{6}{\pi}$ m (D) $\frac{3}{8\pi}$

Q.12 The displacement of a body executing SHM is given by $x = A\sin(2\pi t + \pi/3)$. The first time from t = 0 when the velocity is maximum is

(A) 0.33 sec (B) 0.16 sec (C) 0.25 sec (D) 0.5 sec

Q.13 The maximum acceleration of a particle in SHM is made two times keeping the maximum speed to be constant. It is possible when

(A) amplitude of oscillation is doubled while frequency remains constant

(B) amplitude is doubled while frequency is halved

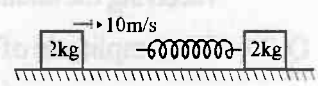
(C) frequency is doubled while amplitude is halved

(D) frequency is doubled while amplitude remains constant

Q.14 The potential energy of a simple harmonic oscillator of mass 2 kg in its mean position is 5 J. If its total energy is 9J and its amplitude is 0.01 m, its time period would be

(A) $\pi/10$ sec (B) $\pi/20$ sec (C) $\pi/50$ sec (D) $\pi/100$ sec

Q.15 A 2 Kg block moving with 10 m/s strikes a spring of constant π^2 N/m attached to 2 Kg block at rest kept on a smooth floor. The time for which rear moving block remain in contact with spring will be



(A) $\sqrt{2}$ sec (B) $\frac{1}{\sqrt{2}}$ sec

(C) 1 sec (D) $\frac{1}{2}$ sec

Q.16 In the above question, the velocity of the rear 2 kg block after its separates from the spring will be :

(A) 0 m/s (B) 5 m/s (C) 10 m/s (D) 7.5 m/s

Q.17 Two particle execute SHM with amplitude A and 2A and angular frequency ω and 2ω respectively. At t = 0 they starts with some initial phase difference. At $t = \frac{2\pi}{3\omega}$. They are in same phase. There initial phase difference is :

(A) $\frac{\pi}{3}$ (B) $\frac{2\pi}{3}$ (C) $\frac{4\pi}{3}$ (D) π

Q.18 A plank with a small block on top of it under going vertical SHM. Its period in 2 sec. The minimum amplitude at which the block will separate from piston is :

(A) $\frac{10}{\pi^2}$ (B) $\frac{\pi^2}{10}$ (C) $\frac{20}{\pi^2}$ (D) $\frac{\pi}{10}$

Q.19 A particle starts oscillating simple harmonically from its equilibrium position then, the ratio of kinetic energy and potential energy of the particle at the time T/12 is : (T = time period)
(A) 2 : 1 (B) 3 : 1 (C) 4 : 1 (D) 1 : 4

Q.20 Time period of a particle executing SHM is 8 sec. At t = 0 it is at the mean position. The ratio of the distance covered by the particle in the 1st second to the 2nd second is :
(A) $\frac{1}{\sqrt{2}+1}$ (B) $\sqrt{2}$ (C) $\frac{1}{\sqrt{2}}$ (D) $\sqrt{2}+1$

Q.21 Two particles are in SHM with same angular frequency and amplitudes A and 2A respectively along same straight line with same mean position. They cross each other at position A/2 distance from mean position in opposite direction. The phase between them is :
(A) $\frac{5\pi}{6}-\sin^{-1}\left(\frac{1}{4}\right)$ (B) $\frac{\pi}{6}-\sin^{-1}\left(\frac{1}{4}\right)$ (C) $\frac{5\pi}{6}-\cos^{-1}\left(\frac{1}{4}\right)$ (D) $\frac{\pi}{6}-\cos^{-1}\left(\frac{1}{4}\right)$

Q.22 A system is oscillating with undamped simple harmonic motion. Then the
(A) average total energy per cycle of the motion is its maximum kinetic energy.
(B) average total energy per cycle of the motion is $\frac{1}{\sqrt{2}}$ times its maximum kinetic energy.
(C) root mean square velocity is $\frac{1}{\sqrt{2}}$ times its maximum velocity
(D) mean velocity is 1/2 of maximum velocity.

Q.23 A particle executing a simple harmonic motion of period 2s. When it is at its extreme displacement from its mean position, it receives an additional energy equal to what it had in its mean position. Due to this, in its subsequent motion,
(A) its amplitude will change and become equal to $\sqrt{2}$ times its previous amplitude
(B) its periodic time will become doubled i.e. 4s
(C) its potential energy will be decreased
(D) it will continue to execute simple harmonic motion of the same amplitude and period as before receiving the additional energy.

Q.24 The amplitude of the vibrating particle due to superposition of two SHMs,
$$y_1 = \sin\left(\omega t + \frac{\pi}{3}\right) \text{ and } y_2 = \sin \omega t \text{ is :}$$
(A) 1 (B) $\sqrt{2}$ (C) $\sqrt{3}$ (D) 2

Q.25 A particle of mass m performs SHM along a straight line with frequency f and amplitude A.
(A) The average kinetic energy of the particle is zero.
(B) The average potential energy is $m\pi^2 f^2 A^2$.
(C) The frequency of ocillation of kinetic energy is 2f.
(D) Velocity function leads acceleration by $\pi/2$.

Q.26 The angular frequency of motion whose equation is $4\frac{d^2y}{dt^2}+9y=0$ is (y = displacement and t = time)
(A) $\frac{9}{4}$ (B) $\frac{4}{9}$ (C) $\frac{3}{2}$ (D) $\frac{2}{3}$

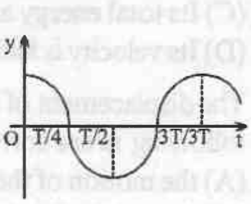
Q.27 The time taken by a particle performing SHM to pass from point A to B where its velocities are same is 2 seconds. After another 2 seconds it returns to B. The time period of oscillation is (in seconds)
(A) 2 (B) 8 (C) 6 (D) 4

Q.28 A block is placed on a horizontal plank. The plank is performing SHM along a vertical line with amplitude of 40cm. The block just loses contact with the plank when the plank is momentarily at rest. Then:
(A) the period of its oscillations is $2\pi/5$ sec.
(B) the block weighs on the plank double its weight, when the plank is at one of the positions of momentary rest.
(C) the block weighs 1.5 times its weight on the plank halfway down from the mean position.
(D) the block weighs its true weight on the plank, when velocity of the plank is maximum.

Q.29 A linear harmonic oscillator of force constant $2 \times 10^6 Nm^{-1}$ and amplitude 0.01 m has a total mechanical energy of 160 J. Its
(A) maximum potential energy is 100 J
(B) maximum kinetic energy is 100 J
(C) maximum potential energy is 160 J
(D) minimum potential energy is zero.

Q.30 A body executes SHM whose period is 16s. Two seconds after it passes the equilibrium position, its velocity is $1 ms^{-1}$. The amplitude of SHM is
(A) 6.3 m (B) 1.8 m (C) 3.6 m (D) 2.4 m

Q.31 The displacement-time graph of a particle executing SHM is shown. Which of the following statements is/are true?
(A) The velocity is maximum at t = T/2
(B) The acceleration is maximum at t = T
(C) The force is zero at t = 3T/4
(D) The potential energy equals the oscillation energy at t = T/2.

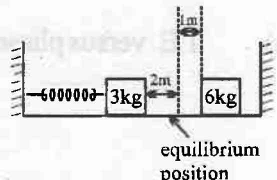


Q.32 The potential energy of a particle of mass 0.1kg, moving along x-axis, is given by $U = 5x(x-4)$J where x is in metres. It can be concluded that
(A) the particle is acted upon by a constant force.
(B) the speed of the particle is maximum at x = 2 m
(C) the particle executes simple harmonic motion
(D) the period of oscillation of the particle is $\pi/5$ s.

Q.33 A mass of 0.2kg is attached to the lower end of a massless spring of force-constant 200 N/m, the upper end of which is fixed to a rigid support. Which of the following statements is/are true?
(A) In equilibrium, the spring will be stretched by 1cm.
(B) If the mass is raised till the spring is unstretched state and then released, it will go down by 2cm before moving upwards.
(C) The frequency of oscillation will be nearly 5 Hz.
(D) If the system is taken to the moon, the frequency of oscillation will be the same as on the earth.

Q.34 A particle is executing SHM with amplitude A, time period T, maximum acceleration a_o and maximum velocity v_0. Its starts from mean position at t=0 and at time t, it has the displacement A/2, acceleration a and velocity v then
(A) t=T/12 (B) $a=a_o/2$ (C) $v=v_o/2$ (D) t=T/8

Q.35 Two blocks of masses 3 kg and 6 kg rest on a horizontal smooth surface. The 3 kg block is attached to a spring with a force constant $k = 900 Nm^{-1}$ which is compressed 2 m from beyond the equilibrium position. The 6 kg mass is at rest at 1m from mean position. 3kg mass strikes the 6 kg mass and the two stick together.



(A) velocity of the combinedmasses immediately after the collision is $10 ms^{-1}$
(B) velocity of the combined masses immediately after thecollision is $5 ms^{-1}$
(C) Amplitude of the resulting oscillation is $\sqrt{2}$ m
(D) Amplitude of the resulting oscillation is $\sqrt{5}/2$ m.

Q.36 Vertical displacement of a plank with a body of mass 'm' on it is varying according to law $y = \sin \omega t + \sqrt{3} \cos \omega t$. The minimum value of ω for which the mass just breaks off the plank and the moment it occurs first after t = 0 are given by: (y is positive vertically upwards)

(A) $\sqrt{\frac{g}{2}} \frac{\sqrt{2}}{6} \frac{\pi}{\sqrt{g}}$ (B) $\frac{g}{\sqrt{2}} \frac{2}{3}\sqrt{\frac{\pi}{g}}$ (C) $\sqrt{\frac{g}{2}}, \frac{\pi}{3}\sqrt{\frac{2}{g}}$ (D) $\sqrt{2g}, \sqrt{\frac{2\pi}{3g}}$

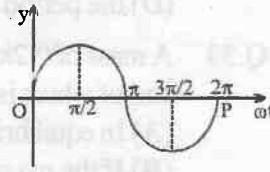
Q.37 A ring of diameter 2m oscillates as a compound pendulum about a horizontal axis passing through a point at its rim. It oscillates such that its centre move in a plane which is perpendicular to the plane of the ring. The equivalent length of the simple pendulum is
(A) 2m (B) 4m (C) 1.5m (D) 3m

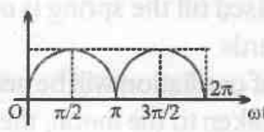
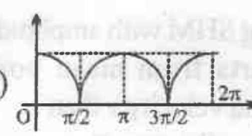
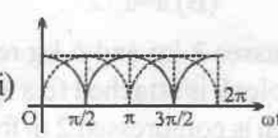
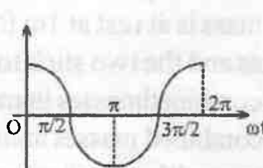
Q.38 The amplitude of a particle executing SHM about O is 10 cm. Then:
(A) When the K.E. is 0.64 of its max. K.E. its displacement is 6cm from O.
(B) When the displacement is 5 cm from O its K.E. is 0.75 of its max.P.E.
(C) Its total energy at any point is equal to its maximum K.E.
(D) Its velocity is half the maximum velocity when its displacement is half the maximum displacement.

Q.39 The displacement of a particle varies according to the relation $x = 3 \sin 100t + 8 \cos^2 50t$. Which of the following is/are correct about this motion.
(A) the motion of the particle is not S.H.M.
(B) theamplitude of the S.H.M. of the particle is 5 units
(C) the amplitude of the resultant S.H. M. is $\sqrt{73}$ units
(D) the maximum displacement of the particle from the origin is 9 units.

Q.40 A spring mass system preforms S.H.M. If the mass is doubled keeping amplitude same, then the total energy of S.H.M. will become :
(A) double (B) half (C) unchanged (D) 4 times

Q.41 The graph plotted between phase angle (ϕ) and displacement of a particle from equilibrium position (y) is a sinusoidal curve as shown below. Then the best matching is



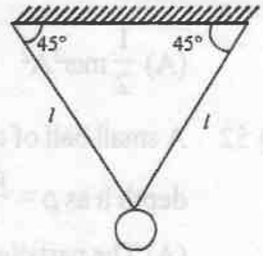
	Column A		Column B
(a)	K.E. versus phase angle curve	(i)	
(b)	P.E. versus phase angle curve	(ii)	
(c)	T.E. versus phase angle curve	(iii)	
(d)	Velocity versus phase angle curve	(iv)	

(A) (a)-(i), (b)-(ii), (c)-(iii) & (d)-(iv) (B) (a)-(ii), (b)-(i), (c)-(iii) & (d)-(iv)
(C) (a)-(ii), (b)-(i), (c)-(iv) & (d)-(iii) (D) (a)-(ii), (b)-(iii), (c)-(iv) & (d)-(i)

Q.42 A liquid of mass m is oscillating with time period T in a U-tube of area of cross-section A. If the liquid is placed in another tube of A/4 cross section area then the time period will be
(A) T (B) 2T (C) T/2 (D) none of these

Q.43 Two particles are in SHM in a straight line. Amplitude A and time period T of both the particles are equal. At time t=0, one particle is at displacement $y_1 = +A$ and the other at $y_2 = -A/2$, and they are approaching towards each other. After what time they cross each other ?
(A) T/3 (B) T/4 (C) 5T/6 (D) T/6

Q.44 Time period of small oscillation (in a vertical plane normal to the plaen of strings) of the bob in the arrangement shown will be:

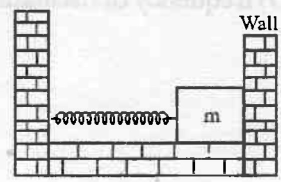


(A) $2\pi\sqrt{\frac{l}{g}}$ (B) $2\pi\sqrt{\frac{l}{\sqrt{2}g}}$

(C) $2\pi\sqrt{\frac{\sqrt{2}l}{g}}$ (D) $2\pi\sqrt{\frac{2l}{g}}$

Q.45 A particle performs SHM in a straight line. In the first second, starting from rest, it travels a distance a and in the next second it travels a distance b in the same direction. The amplitude of the SHM is:
(A) a – b (B) $\frac{2a-b}{3}$ (C) $\frac{2a^2}{3a-b}$ (D) none of these

Q.46 In the figure, the block of mass m, attached to the spring of stiffness k is in contact with the completely elastic wall, and the compression in the spring is 'e'. The spring is compressed further by 'e' by displacing the blocktowards left and is then released. If the collision between the block and the wall is completely elastic then the time period of oscillations of the block will be:



(A) $\frac{2\pi}{3}\sqrt{\frac{m}{k}}$ (B) $2\pi\sqrt{\frac{m}{k}}$

(C) $\frac{\pi}{3}\sqrt{\frac{m}{k}}$ (D) $\frac{\pi}{6}\sqrt{\frac{m}{k}}$

Q.47 The potential energy of a harmonic oscillator of mass 2 kg in its mean position is 5J. If its total energy is 9J, and its amplitude is 0.01 m, its time period would be:
(A) (π/100)s (B) (π/50)s (C) (π/20)s (D) (π/10)s

Q.48 The angular frequency of a spring block system is ω_0. This system is suspended from the ceiling of an elevator moving downwards with a constant speed v_0. The block is at rest relative to the elevator. Lift is suddenly stopped. Assuming the downwards as a positive direction, choose the wrong statement:

(A) The amplitude of the block is $\frac{v_0}{\omega_0}$

(B) The initial phase of the block is π.

(C) The equation of motion for the block is $\frac{v_0}{\omega_0}$ sin ω_0t.

(D) The maximum speed of the block is v_0.

Q.49 Two pendulums have time periods T and 5T/4. They start SHM at the same time from the mean position. After how many oscillations of the smaller pendulum they will be again in the same phase:
(A) 5 (B) 4 (C) 11 (D) 9

Q.50 In SHM, acceleration versus displacement (from mean position) graph:
(A) is always a straight line passing through origin and slope −1
(B) is always a straight line passing through origin and slope +1
(C) is a straight line not necessarily passing through origin
(D) none of the above

Q.51 Two simple harmonic motions $y_1 = A \sin \omega t$ and $y_2 = A \cos \omega t$ are superimposed on a particle of mass m. The total mechanical energy of the particle is:
(A) $\frac{1}{2} m\omega^2 A^2$ (B) $m\omega^2 A^2$ (C) $\frac{1}{4} m\omega^2 A^2$ (D) zero

Q.52 A small ball of density ρ_0 is released from rest from the surface of a liquid whose density varies with depth h as $\rho = \frac{\rho_0}{2}(\alpha + \beta h)$. Mass of the ball is m. Select the most appropriate one option.
(A) The particle will execute SHM
(B) The maximum speed of the ball is $\frac{2-\alpha}{\sqrt{2\beta}}$
(C) Both (A) and (B) are correct
(D) Both (A) and (B) are wrong
(Here α and β are positive constant of proper dimensions with $\alpha < 2$)

Q.53 The maximum acceleration of a particle in SHM is made two times keeping the maximum speed to be constant. It is possible when:
(A) amplitude of oscillation is doubled while frequency remains constant
(B) amplitude is doubled while frequency is halved.
(C) frequency is doubled while amplitude is halved.
(D) frequency of oscillation is doubled while amplitude remains constant

ANSWER KEY

Q.1	C	Q.2	C	Q.3	B	Q.4	A
Q.5	A	Q.6	C	Q.7	B	Q.8	B
Q.9	A	Q.10	B	Q.11	A	Q.12	A
Q.13	C	Q.14	D	Q.15	C	Q.16	A
Q.17	B, C	Q.18	A	Q.19	B	Q.20	D
Q.21	A	Q.22	A, C	Q.23	A	Q.24	C
Q.25	B, C	Q.26	C	Q.27	B	Q.28	A, B, C, D
Q.29	B, C	Q.30	C	Q.31	B, C, D	Q.32	B, C, D
Q.33	A, B, C, D	Q.34	A, B	Q.35	A, C	Q.36	A
Q.37	C	Q.38	A, B, C	Q.39	B, D	Q.40	C
Q.41	B	Q.42	B	Q.43	D	Q.44	B
Q.45	C	Q.46	A	Q.47	A	Q.48	B
Q.49	A	Q.50	D	Q.51	B	Q.52	A
Q.53	C						

BANSAL CLASSES

PHYSICS

TARGET IIT JEE 2007
XI (P, Q, R, S)

UNITS & DIMENSIONS
&
BASIC MATHEMATICS

CONTENTS

EXERCISE
ANSWER KEY

EXERCISE

Q.1 If force, acceleration and time are taken as fundamental quantities, then the dimensions of length will be:
(A) FT^2 (B) $F^{-1}A^2T^{-1}$ (C) FA^2T (D) AT^2

Q.2 In a certain system of units, 1 unit of time is 5 sec, 1 unit of mass is 20 kg and unit of length is 10 m. In this system, one unit of power will correspond to
(A) 16 watts (B) $\frac{1}{16}$ watts (C) 25 watts (D) none of these

Q.3 Three forces P, Q & R are acting at a point in the plane. The angle between P & Q and Q & R are 150° & 120° respectively, then for equilibrium, forces P, Q & R are in the ratio
(A) 1 : 2 : 3 (B) 1 : 2 : $\sqrt{3}$ (C) 3 : 2 : 1 (D) $\sqrt{3}$: 2 : 1

Q.4 The resultant of two forces F_1 and F_2 is P. If F_2 is reversed, then resultant is Q. Then the value of $(P^2 + Q^2)$ in terms of F_1 and F_2 is
(A) $2(F_1^2 + F_2^2)$ (B) $F_1^2 + F_2^2$ (C) $(F_1 + F_2)^2$ (D) none of these

Q.5 A man rows a boat with a speed of 18km/hr in northwest direction. The shoreline makes an angle of 15° south of west. Obtain the component of the velocity of the boat along the shoreline.
(A) 9 km/hr (B) $18\frac{\sqrt{3}}{2}$ km/hr (C) 18 cos15°km/hr (D) 18 cos75° km/hr

Q.6 A bird moves from point $(1, -2, 3)$ to $(4, 2, 3)$. If the speed of the bird is 10 m/sec, then the velocity vector of the bird is :
(A) $5(\hat{i}-2\hat{j}+3\hat{k})$ (B) $5(4\hat{i}+2\hat{j}+3\hat{k})$ (C) $0.6\hat{i}+0.8\hat{j}$ (D) $6\hat{i}+8\hat{j}$

Q.7 The dimensions $ML^{-1}T^{-2}$ can correspond to :
(A) moment of a force or torque (B) surface tension
(C) pressure (D) co-efficient of viscosity.
(useful relation are $\vec{\tau} = \vec{r} \times \vec{F}$, $S = F/l$, $F = 6\pi\eta r v$, where symbols have usual meaning)

Q.8 The pressure of 10^6 dyne/cm^2 is equivalent to
(A) 10^5 N/m^2 (B) 10^6 N/m^2 (C) 10^7 N/m^2 (D) 10^8 N/m^2

Q.9 If area (A) velocity (v) and density (ρ) are base units, then the dimensional formula of force can be represented as.
(A) $Av\rho$ (B) $Av^2\rho$ (C) $Av\rho^2$ (D) $A^2v\rho$

Q.10 If the resultant of two forces of magnitudes P and Q acting at a point at an angle of 60° is $\sqrt{7}$ Q, then P / Q is
(A) 1 (B) 3 / 2 (C) 2 (D) 4

Q.11 For a particle moving in a straight line, the position of the particle at time (t) is given by
$$x = t^3 - 6t^2 + 3t + 7$$
what is the velocity of the particle when it's acceleration is zero ?
(A) – 9 ms^{-1} (B) – 12 ms^{-1} (C) 3 ms^{-1} (D) 42 ms^{-1}

Q.12 If the angle between the unit vectors $\hat{a}$ and $\hat{b}$ is 60°, then $|\hat{a} - \hat{b}|$ is
(A) 0 (B) 1 (C) 2 (D) 4

Q.13 In a book, the answer for a particular question is expressed as

$$b = \frac{ma}{k}\left[\sqrt{1+\frac{2kl}{ma}}\right]$$

here m represents mass, a represents accelerations, l represents length. The unit of b should be
(A) m/s (B) m/s^2 (C) meter (D) / sec.

Q.14 The resultant of two forces, one double the other in magnitude is perpendicular to the smaller of the two forces. The angle between the two forces is
(A) 150° (B) 90° (C) 60° (D) 120°

Q.15 Which of the following can be a set of fundamental quantities
(A) length, velocity, time (B) momentum, mass, velocity
(C) force, mass, velocity (D) momentum, time, frequency

Q.16 If 1 unit of mass = 4 kg; 1 unit of length = $\frac{1}{4}$ m and 1 unit of time = 5 sec, then 1 Joule = x units of energy in this system where x =
(A) 100 units (B) 0.01 units (C) 200 units (D) 0.02 units

Q.17 A man moves towards 3 m north then 4 m towards east and finally 5m towards south west. His displacement from origin is
(A) $5\sqrt{2}$ m (B) 0 m (C) 12 m (D) 5 m

Q.18 Kinetic energy (K) depends upon momentum (p) and mass (m) of a body as $K \propto p^a m^b$
(A) a = 1; b = 1 (B) a = 2; b = –1 (C) a = 2; b = 1 (D) a = 1; b = 2

Q.19 Use the approximation $(1+x)^n \approx 1 + nx$, $|x| << 1$, to find approximate value for
(a) $\sqrt{99}$ (b) $\frac{1}{1.01}$ (c) $124^{1/3}$

Q.20 A particle is in a uni-directional potential field where the potential energy (U) of a particle depends on the x-cordinate given by $U_x = k(1 - \cos ax)$ & k and 'a' are constants. Find the physical dimensions of 'a' & k.

Q.21 An enclosed ideal gas A has its pressure P as a function of its volume V as $P = P_0 - \alpha V^2$, where P_0 & α are constants. Find the physical dimensions of α.

Q.22 Use the small angle approximations to find approximate values for (a) sin 8° and (b) tan 5°

Q.23 When two forces of magnitude P and Q are perpendicular to each other, their resultant is of magnitude R. When they are at an angle of 180° to each other their resultant is of magnitude $\frac{R}{\sqrt{2}}$. Find the ratio of P and Q.

Q.24 A particle moves along the space curve $\vec{r} = (t^2+t)\hat{i} + (3t-2)\hat{j} + (2t^3-4t^2)\hat{k}$.(t in sec, r in m) Find at time t = 2 the (a) velocity, (b) acceleration, (c) speed or magnitude of velocity and (d) magnitude of acceleration .

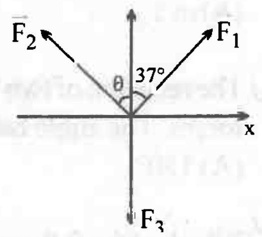
Q.25 The time period (T) of a spring mass system depends upon mass (m) & spring constant (k) & length of the spring (l) [$k = \frac{\text{Force}}{\text{length}}$]. Find the relation among, (T), (m), (l) & (k) using dimensional method.

Q.26 A body acted upon by 3 given forces is under equilibrium.

(a) If $|\vec{F}_1| = 10$ Nt., $|\vec{F}_2| = 6$ Nt.

Find the values of $|\vec{F}_3|$ & angle (θ).

(b) Express $\vec{F}_2$ in unit vector form.



Q.27 A particle is acted upon by the forces $\vec{F}_1 = 2\hat{i} + a\hat{j} - 3\hat{k}$, $\vec{F}_2 = 5\hat{i} + c\hat{j} - b\hat{k}$, $\vec{F}_3 = b\hat{i} + 5\hat{j} - 7\hat{k}$, $\vec{F}_4 = c\hat{i} + 6\hat{j} - a\hat{k}$, . Find the values of the constants a, b, c in order that the particle will be in equilibrium.

Q.28 A satellite is orbiting around a planet. Its orbital velocity (v_0) is found to depend upon

(a) Radius of orbit (R)

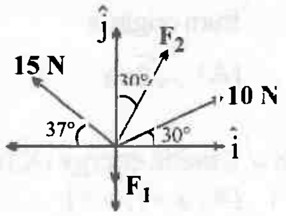
(b) Mass of planet (M)

(c) Universal gravitation constant (G)

Using dimensional analysis find an expression relating orbital velocity (v_0) to the above physical quantities.

Q.29 If the four forces as shown are in equilibrium

Express $\vec{F}_1$ & $\vec{F}_2$ in unit vector form .



Q.30 The equation of state for a real gas at high temperature is given by $P = \frac{nRT}{V-b} - \frac{a}{T^{1/2}V(V+b)}$

where n, P, V & T are number of moles, pressure, volume & temperature respectively & R is the universal gas constant . Find the dimensions of constant 'a' in the above equation.

Q.31 The distance moved by a particle in time t from centre of a ring under the influence of its gravity is given by $x = a\sin\omega t$ where a & ω are constants. If ω is found to depend on the radius of the ring (r), its mass (m) and universal gravitational constant (G), find using dimensional analysis an expression for ω in terms of r, m and G.

Q.32 If the velocity of light c, Gravitational constant G & Plank's constant h be chosen as fundamental units, find the dimension of mass, length & time in the new system.

Q.33 A plane body has perpendicular axes OX and OY marked on it and is acted on by following forces

5P in the direction OY

4P in the direction OX

10P in the direction OA where A is the point (3a, 4a)

15P in the direction AB where B is the point (– a, a)

Express each force in the unit vector form & calculate the magnitude & direction of sum of the vector of these forces.

Q.34 Two vectors have magnitudes 3 unit and 4 unit respectively. What should be the angle between them if the magnitude of the resultant is (a) 1 unit, (b) 5 unit and (c) 7 unit.

Q.35 A vector $\vec{A}$ of length 10 units makes an angle of 60° with a vector $\vec{B}$ of length 6 units. Find the magnitude of the vector difference $\vec{A}-\vec{B}$ & the angle it makes with vector $\vec{A}$.

Q.36 At time t the position vector of a particle of mass m = 3kg is given by $\vec{r} = 6t\,\hat{i} - t^3\hat{j} + \cos t\,\hat{k}$. Find the resultant force $\vec{F}(t)$, magnitude of its acceleration when $t = \frac{\pi}{2}$ & speed when $t = \pi$.

Q.37 Given that the position vector of a particle moving in x-y plane is given by $\vec{r} = (t^2-4)\hat{i} + (t-4)\hat{j}$. Find

(a) Equation of trajectory of the particle

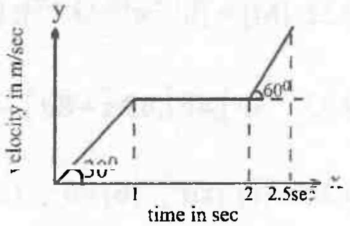
(b) Time when it crosses x-axis and y-axis

Q.38 The velocity time graph of a body moving in a straight line is shown. Find its

(a) instantaneous velocity at t = 1.5 sec.

(b) average acceleration from t = 1.5 sec. to t = 2.5 sec.

(c) draw its acceleration time graph from t = 0 to t = 2.5 sec



Q.39 The curvilinear motion of a particle is defined by v_x=50-16t and y=100-4t^2, where v_x is in metres per second, y is in metres and t is in seconds. It is also known that x=0 when t=0. Determine the velocity (**v**) and acceleration(**a**) when the position y=0 is reached.

Q.40 The force acting on a body moving in a straight line is given by F = (3t^2 – 4t + 1) Newton where t is in sec. If mass of the body is 1kg and initially it was at rest at origin. Find

(a) displacement between time t = 0 and t = 2 sec.

(b) distance travelled between time t = 0 and t = 2 sec.

ANSWER KEY

EXERCISE # I

Q.1 D	Q.2 A	Q.3 D	Q.4 A	Q.5 A
Q.6 D	Q.7 C	Q.8 A	Q.9 B	Q.10 C
Q.11 A	Q.12 B	Q.13 C	Q.14 D	Q.15 C
Q.16 A	Q.17 B	Q.18 B	Q.19 (a) 9.95, (b) 0.99, (c) 4.986	

Q.20 L^{-1}, ML^2T^{-2} Q.21 $ML^{-7}T^{-2}$ Q.22 0.14, 0.09

Q.23 $2 \pm \sqrt{3}$

Q.24 (a) $5i + 3j + 8k$, (b) $2i + 16k$, (c) $7\sqrt{2}$, (d) $2\sqrt{65}$

Q.25 $T = a\sqrt{\frac{m}{k}}$ Q.26 (a) $\vec{F}_3 = 14$ N, (b) $\vec{F}_2 = -6\hat{i}$

Q.27 $a = -7, b = -3, c = -4$ Q.28 $v_0 = k\sqrt{\frac{GM}{R}}$

Q.29 $\vec{F}_1(29-12\sqrt{3})\left(-\hat{j}\right)$ Q.30 $ML^5T^{-2}K^{1/2}$ Q.31 $\omega = K\sqrt{\frac{Gm}{r^3}}$

Q.32 $[M] = [h^{1/2} \cdot c^{1/2} \cdot G^{-1/2}]$; $[L] = [h^{1/2} \cdot c^{-3/2} \cdot G^{1/2}]$; $[T] = [h^{1/2} \cdot c^{-5/2} \cdot G^{1/2}]$

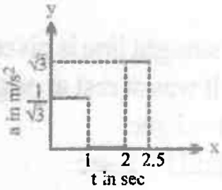
Q.33 $5P\hat{j}, 4P\hat{i}, 6P\hat{i} + 8P\hat{j}, -12P\hat{i} - 9P\hat{j}, \sqrt{20}, \tan^{-1}[-2]$ with the +ve x axis

Q.34 (a) 180°, (b) 90°, (c) 0 Q.35 $2\sqrt{19}$; $\cos^{-1}\frac{7}{2\sqrt{19}}$

Q.36 $-18t\,\hat{j} - 3\cos t\,\hat{k}$; 3π; $3\sqrt{4+\pi^4}$

Q.37 (a) $y^2 + 8y + 12 = x$; (b) crosses x axis when t = 4 sec., crosses y axis when t = ± 2 sec.

Q.38 (a) $\frac{1}{\sqrt{3}}$ m/s , (b) $\frac{\sqrt{3}}{2}$ m/s^2 , (c)



Q.39 $\vec{v} = -30\hat{i} - 40\hat{j}$, $\vec{a} = -16\hat{i} - 8\hat{j}$ Q.40 (a) $\frac{2}{3}$ m, (b) t = 0, 1

BANSALCLASSES

TARGET IIT JEE 2007

PHYSICS

XII (ALL)

QUESTION BANK ON

WAVE OPTICS

SHORT QUESTIONS

Q.1 A person wets his eyeglass to clean them. As the water evaporates he notices that for a short time the glass become markedly more non reflecting. Explain.

Q.2 A lens is coated to reduce reflection. What happens to the energy that had previously been reflected? Is it absorbed by the coating?

Q.3 If interference between light waves of different frequencies is possible, one should observe light beats, just as one obtains sound beats from two sources of sound with slightly different frequencies. Discuss how one might experimentally look for this possibility.

Q.4 What is the shape of interference fringes as seen on a screen perpendicular to the line joining the sources in Young's interference experiment if the source are (a) pinholes, (b) slits?

Q.5 In Young's double slit experiment why must the slits be close and of same width?

Q.6 In Young's double slit experiment why do we use monochromatic light ? If white light is used, how would the pattern change?

Q.7 Will interference be observed in Young's double-slit experiment if the light from a source falls directly on the two slits?

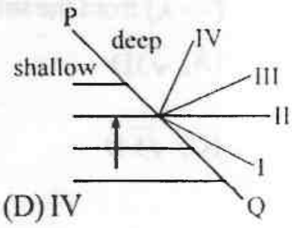
Q.8 In what direction will the fringe system shift if a glass plate is interposed in the path of one of the interfering beams?

Q.9 Suppose that a radio station broadcasts simultaneously from two transmitting antennas at two different locations. Is it clear that your radio will have better reception with two transmitting antennas rather than one? Justify your answer.

ONLY ONE OPTION IS CORRECT.

Take approx. 2 minutes for answering each question.

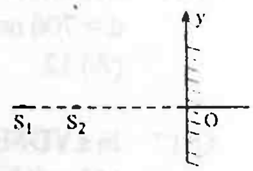
Q.1 Figure, shows wave fronts in still water, moving in the direction of the arrow towards the interface PQ between a shallow region and a deep(denser) region. Which of the lines shown may represent one of the wave fronts in the deep region?



(A) I (B) II (C) III (D) IV

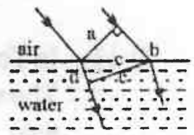
Q.2 Two coherent monochromatic light beams of intensities I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are :
(A) 5I and I (B) 5I and 3I (C) 9I and I (D) 9I and 3I

Q.3 Two point monochromatic and coherent sources of light of wavelength l are placed on the dotted line in front of an large screen. The source emit waves in phase with each other. The distance between S_1 and S_2 is 'd' while their distance from the screen is much larger. Then,



(1) → If d = 7λ/2, O will be a minima
(2) → If d = 4.3λ, there will be a total of 8 minima on y axis.
(3) → If d = 7λ, O will be a maxima.
(4) → If d = λ, there will be only one maxima on the screen.
Which is the set of correct statement :
(A) 1, 2 & 3 (B) 2, 3 & 4 (C) 1, 2, 3 & 4 (D) 1, 3 & 4

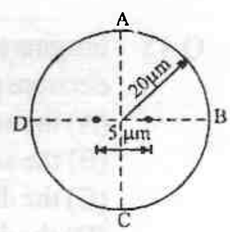
Q.4 Figure shown plane waves refracted for air to water using Huygen's principle a, b, c, d, e are lengths on the diagram. The refractive index of water wrt air is the ratio.



(A) a/e (B) b/e (C) b/d (D) d/b

Q.5 When light is refracted into a denser medium,
(A) its wavelength and frequeny both increases
(B) its wavelength increase but freqnency remains unchanged
(C) its wavelength decrease but freqnency remains unchanged
(D) its wavelength and freqnency both decrease.

Q.6 Two point source separated by d = 5 μm emit light of wavelength λ = 2 μm in phase. A circular wire of radius 20 μm is placed around the source as shown in figure.

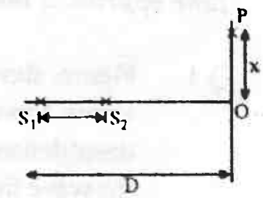


(A) Point A and B are dark and points C and D are bright.
(B) Points A and B are bright and point C and D are dark.
(C) Points A and C are dark and points B and D are bright.
(D) Points A and C are bright and points B and D are dark.

Q.7 Plane microwaves from a transmitter are directed normally towards a plane reflector. A detector moves along the normal to the reflector. Between positions of 14 successive maxima, the detector travels a distance 0.13 m. If the velocity of light is 3×10^8 m/s, find the frequency of the transmitter.
(A) 1.5×10^{10} Hz (B) 10^{10} Hz (C) 3×10^{10} Hz (D) 6×10^{10} Hz

Q.8 Two monochromatic (wavelength = a/5) and coherent sources of electromagnetic waves are placed on the x-axis at the points (2a, 0) and (–a, 0). A detector moves in a circle of radius R(>>2a) whose centre is at the origin. The number of maximas detected during one circular revolution by the detector are
(A) 60 (B) 15 (C) 64 (D) None

Q.9 Two coherent narrow slits emitting light of wavelength λ in the same phase are placed parallel to each other at a small separation of 3λ. The light is collected on a screen S which is placed at a distance D (>> λ) from the slits. The smallest distance x such that the P is a maxima



(A) $\sqrt{3}D$ (B) $\sqrt{8}\,D$

(C) $\sqrt{5}\,D$ (D) $\sqrt{5}\,\frac{D}{2}$

Q.10 Two coherent sources of light are placed at points $(-\frac{5a}{2}, 0)$ and $(+\frac{5a}{2}, 0)$. Wavelength of the light is $\lambda = \frac{4a}{3}$. How many maximas will be obtained on a CD planar circle of large radius with centre at origin.

(A) 12 (B) 15 (C) 16 (D) 14

Q.11 In YDSE how many maxima can be obtained on the screen if wavelength of light used is 200nm and d = 700 nm:

(A) 12 (B) 7 (C) 18 (D) none of these

Q.12 In a YDSE, the central bright fringe can be identified :

(A) as it has greater intensity than the other bright fringes.

(B) as it is wider than the other bright fringes.

(C) as it is narrower than the other bright fringes.

(D) by using white light instead of single wavelength light.

Q.13 In Young's double slit experiment, the wavelength of red light is 7800 Å and that of blue light is 5200 Å. The value of n for which n^{th} bright band due to red light coincides with $(n + 1)^{th}$ bright band due to blue light, is :

(A) 1 (B) 2 (C) 3 (D) 4

Q.14 If the Young's double slit experiment is performed with white light, then which of the following is not true.

(A) the central maximum will be white (B) there will not be a completely dark fringe

(C) the fringe next to the central will be red (D) the fringe next to the central will be violet

Q.15 Imagine a Young's double slit interference experiment performed with waves associated with fast moving electrons produced from an electron gun. The distance between successive maxima will decrease maximum if

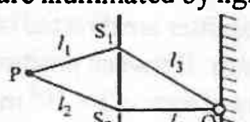
(A) the accelerating voltage in the electron gun is decreased

(B) the accelerating voltage is increased and the distance of the screen from the slits is decreased

(C) the distance of the screen from the slits is increased.

(D) the distance between the slits is decreased.

Q.16 Two identical narrow slits S_1 and S_2 are illuminated by light of wavelength λ from a point source P.



If, as shown in the diagram above the light is then allowed to fall on a screen, and if n is a positive integer, the condition for destructive interference at Q is that

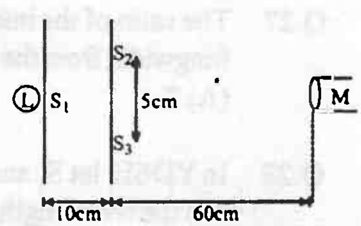
(A) $(l_1 - l_2) = (2n + 1)\lambda/2$ (B) $(l_3 - l_4) = (2n + 1)\lambda/2$

(C) $(l_1 + l_2) - (l_2 + l_4) = n\lambda$ (D) $(l_1 + l_3) - (l_2 + l_4) = (2n + 1)\lambda/2$

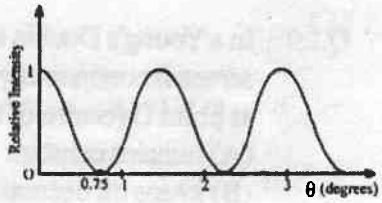
Q.17 In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and wavelength λ. In another experiment with the same setup the two slits are sources of equal amplitude A and wavelength λ but are incoherent. The ratio of the intensity of light at the midpoint of the screen in the first case to that in the second case is
(A) 1 : 1 (B) 2 : 1 (C) 4 : 1 (D) none of these

Q.18 In a Young's double slit experiment, a small detector measures an intensity of illumination of I units at the centre of the fringe pattern. If one of the two (identical) slits is now covered, the measured intensity will be
(A) 2I (B) I (C) I/4 (D) I/2

Q.19 A student is asked to measure the wavelength of monochromatic light. He sets up the apparatus sketched below. S_1, S_2, S_3 are narrow parallel slits, L is a sodium lamp and M is a microscope eyepiece. The student fails to observe interference fringes. Your first advice to him will be
(A) increase the width of S_1
(B) decrease the distance between S_2 and S_3
(C) replace L with a white light source
(D) replace M with a telescope
(E) make S_2 and S_3 wider.



Q.20 Light of wavelength 520 nm passing through a double slit, produces interference pattern of relative intensity versus deflection angle θ as shown in the figure. The separation d between the slits is
(A) 2×10^{-2} mm (B) 5×10^{-2} mm
(C) 4.5×10^{-2} mm (D) 1.1×10^{-2} mm



Q.21 In Young's double slit experiment the slits are 0.5 mm apart and the interference is observed on a screen at a distance of 100 cm from the slit. It is found that the 9th bright fringe is at a distance of 7.5 mm from the second dark fringe from the centre of the fringe pattern. The wavelength of the light used is
(A) $\frac{2500}{7}$ Å (B) 2500 Å (C) 5000 Å (D) $\frac{5000}{7}$ Å

Q.22 In a YDSE apparatus, two identical slits are separated by 1 mm and distance between slits and screen is 1 m. The wavelength of light used is 6000 Å. The minimum distance between two points on the screen having 75% intensity of the maximum intensity is :
(A) 0.45 mm (B) 0.40 mm (C) 0.30 mm (D) 0.20 mm

Q.23 In a young double slit experiment D equals the distance of screen and d is the separation between the slit. The distance of the nearest point to the central maximum where the intensity is same as that due to a single slit, is equal to
(A) $\frac{D\lambda}{d}$ (B) $\frac{D\lambda}{2d}$ (C) $\frac{D\lambda}{3d}$ (D) $\frac{2D\lambda}{d}$

Q.24 A beam of light consisting of two wavelength 6300 Å and λ Å is used to obtain interference fringes in a Young's double slit experiment. If 4[th] bright fringe of 6300 Å coincides with 5[th] dark fringe of λ Å, the value of λ (in Å) is
(A) 5200 (B) 4800 (C) 6200 (D) 5600

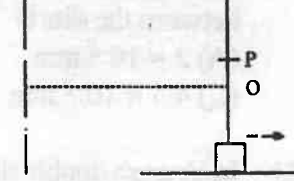
Q.25 A beam of light consisting of two wavelengths 6500Å and 5200Å is used to obtain interference fringes in Young's double slit experiment. The distance between slits is 2 mm and the distance of screen from slits is 120 cm. What is the least distance from central maximum where the bright due to both wavelength coincide?
(A) 0.156 cm (B) 0.312 cm (C) 0.078 cm (D) 0.468 cm

Q.26 In a two slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-5} m. If separation between the slits is 10^{-3}m, the wavelength of light used is:
(A) 6000 Å (B) 5000 Å (C) 3000 Å (D) 4500 Å

Q.27 The ratio of the intensity at the çentre of a bright fringe to the intensity at a point one–quarter of the fringwidth from the centre is
(A) 2 (B) 1/2 (C) 4 (D) 16

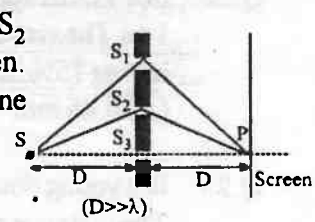
Q.28 In YDSE, let S_1 and S_2 be the two slits, and C be the centre of the screen. If θ is the angle S_1CS_2 and λ is the wavelength, the fringe width will be :
(A) $\frac{\lambda}{\theta}$ (B) $\lambda\theta$ (C) $\frac{2\lambda}{\theta}$ (D) $\frac{\lambda}{2\theta}$

Q.29 In a Young's Double slit experiment, first maxima is observed at a fixed point P on the screen. Now the screen is continuously moved away from the plane of slits. The ratio of intensity at point P to the intensity at point O (centre of the screen)
(A) remains constant
(B) keeps on decreasing
(C) first decreases and then increases
(D) First decreases and then becomes constant



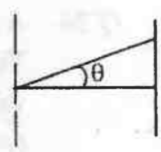
Q.30 In a double slit experiment, the separation between the slits is d = 0.25 cm and the distance of the screen D = 100 cm from the slits. If the wavelength of light used is $\lambda = 6000$Å and I_0 is the intensity of the central bright fringe, the intensity at a distance $x = 4 \times 10^{-5}$ m from the central maximum is
(A) I_0 (B) $I_0/2$ (C) $3I_0/4$ (D) $I_0/3$

Q.31 A monochromatic light source of wavelength λ is placed at S. Three slits S_1, S_2 and S_3 are equidistant from the source S and the point P on the screen. $S_1P - S_2P = \lambda/6$ and $S_1P - S_3P = 2\lambda/3$. If I be the intensity at P when only one slit is open, the intensity at P when all the three slits are open is
(A) 3 I (B) 5 I
(C) 8 I (D) zero

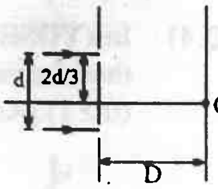


Q.32 In young's double slit experiment, the value of $\lambda = 500$ nm. The value of d = 1 mm, D = 1 m. Then the minimum distance from central maximum for which the intensity is half the maximum intensity will be
(A) 2.5×10^{-4} m (B) 2×10^{-4} m (C) 1.25×10^{-4} m (D) 10^{-4} m

Q.33 Two slits are separated by 0.3 mm. A beam of 500 nm light strikes the slits producing an interference pattern. The number of maxima observed in the angular range $-30° < \theta < 30°$.
(A) 300 (B) 150
(C) 599 (D) 149



Q.34 In the figure shown if a parallel beam of white light is incident on the plane of the slits then the distance of the white spot on the screen from O is [Assume $d << D$, $\lambda << d$]



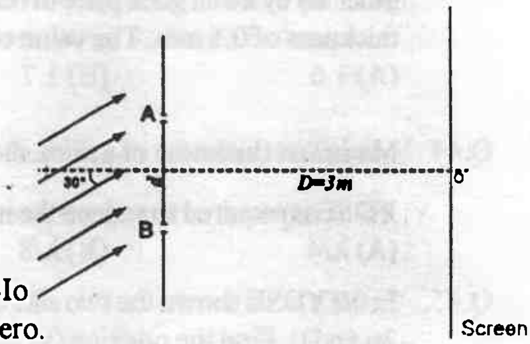
(A) 0 (B) d/2
(C) d/3 (D) d/6

Q.35 In the above question if the light incident is monochromatic and point O is a maxima, then the wavelength of the light incident cannot be

(A) $d^2/3D$ (B) $d^2/6D$
(C) $d^2/12D$ (D) $d^2/18D$

Q.36 In Young's double slit arrangement, water is filled in the space between screen and slits. Then :
(A) fringe pattern shifts upwards but fringe width remains unchanged.
(B) fringe width decreases and central bright fringe shifts upwards.
(C) fringe width increases and central bright fringe does not shift.
(D) fringe width decreases and central bright fringe does not shift.

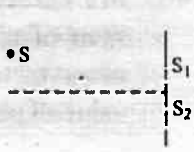
Q.37 A parallel beam of light 500nm is incident at an angle 30° with the normal to the slit plane in a young's double slit experiment. The intensity due to each slit is Io. Point O is equidistant from S_1 and S_2. The distance between slits is 1mm.
(A) the intensity at O is 4Io
(B) the intensity at O is zero.
(C) the intensity at a point on the screen 4mm from O is 4Io
(D) the intensity at a point on the screen 4mm from O is zero.



Q.38 Light of wavelength λ in air enters a medium of refractive index μ. Two points in this medium, lying along the path of this light, are at a distance x apart. The phase difference between these points is :

(A) $\frac{2\pi\mu x}{\lambda}$ (B) $\frac{2\pi x}{\mu\lambda}$ (C) $\frac{2\pi(\mu-1)x}{\lambda}$ (D) $\frac{2\pi x}{(\mu-1)\lambda}$

Q.39 In YDSE, the source placed symmetrically with respect to the slit is now moved parallel to the plane of the slits so that it is closer to the upper slit, as shown. Then,

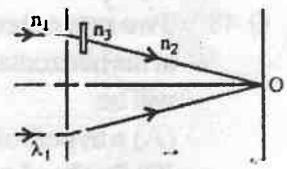


(A) the fringe width will increase and fringe pattern will shift down.
(B) the fringe width will remain same but fringe pattern will shift up.
(C) the fringe width will decrease and fringe pattern will shift down.
(D) the fringe width will remain same but fringe pattern will shift down.

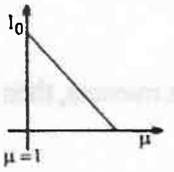
Q.40 In the figure shown in YDSE, a parallel beam of light is incident on the slit from a medium of refractive index n_1. The wavelength of light in this medium is λ_1. A transparent slab of thickness 't' and refractive index n_3 is put infront of one slit. The medium between the screen and the plane of the slits is n_2. The phase difference between the light waves reaching point 'O' (symmetrical, relative to the slits) is :

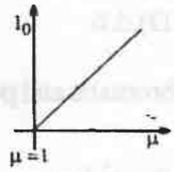
(A) $\frac{2\pi}{n_1\lambda_1}(n_3-n_2)t$ (B) $\frac{2\pi}{\lambda_1}(n_3-n_2)t$

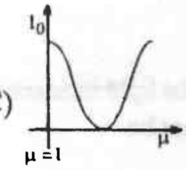
(C) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2}-1\right)t$ (D) $\frac{2\pi n_1}{\lambda_1}(n_3-n_1)t$

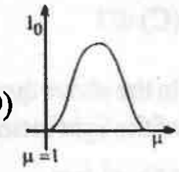


Q.41 In a YDSE experiment if a slab whose refractive index can be varied is placed in front of one of the slits then the variation of resultant intensity at mid-point of screen with 'μ' will be best represented by ($\mu \geq 1$). [Assume slits of equal width and there is no absorption by slab]

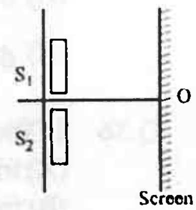
(A) 

(B) 

(C) 

(D) 

Q.42 Young's double slit experiment is carried with two thin sheets of thickness 10.4 μm each and refractive index $\mu_1 = 1.52$ and $\mu_2 = 1.40$ covering the slits S_1 and S_2, respectively. If white light of range 400 nm to 780 nm is used then which wavelength will form maxima exactly at point O, the centre of the screen?

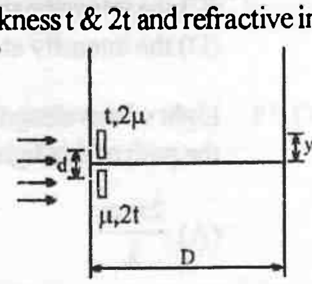


(A) 416 nm only (B) 624 nm only
(C) 416 nm and 624 nm only (D) none of these

Q.43 A light of wavelength 6300Å shine on a two narrow slits separated by a distance 1.0 mm and illuminates a screen at a distance 1.5 m away. When one slit is covered by a thin glass of refractive index 1.8 and other slit by a thin glass plate of refractive index μ, the central maxima shifts by 6°. Both plates have same thickness of 0.5 mm. The value of refractive index μ of the plate is
(A) 1.6 (B) 1.7 (C) 1.5 (D) 1.4

Q.44 Minimum thickness of a mica sheet having $\mu = \frac{3}{2}$ which shoule be placed in front of one of the slits in YDSE is required to reduce the intensity at the centre of screen to half of maximum intensity is
(A) $\lambda/4$ (B) $\lambda/8$ (C) $\lambda/2$ (D) $\lambda/3$

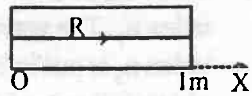
Q.45 In the YDSE shown the two slits are covered with thin sheets having thickness t & 2t and refractive index 2μ and μ. Find the position (y) of central maxima



(A) zero (B) $\frac{tD}{d}$
(C) $-\frac{tD}{d}$ (D) None

Q.46 In a YDSE with two identical slits, when the upper slits is covered with a thin, perfectly transparent sheet of mica, the intensity at the centre of screen reduces to 75% of the initial value. Second minima is observed to be above this point and third maxima below it. Which of the following can not be a possible value of phase difference caused by the mica sheet
(A) $\frac{\pi}{3}$ (B) $\frac{13\pi}{3}$ (C) $\frac{17\pi}{3}$ (D) $\frac{11\pi}{3}$

Q.47 The figure shows a transparent slab of length 1m placed in air whose refractive index in x direction varies as $\mu = 1 + x^2 (0 \leq x \leq 1)$. The optical path length of ray R will be



(A) 1 m (B) $\frac{2}{3}$ m
(C) $\frac{4}{3}$ m (D) $\sqrt{2}$ m

Q.48 Two monochromatic and coherent point sources of light are placed at a certain distance from each other in the horizontal plane. The locus of all those points in the horizontal plane which have construct interference will be
(A) a hyperbola (B) family of hyperbolas
(C) family of straight lines (D) family of parabolas

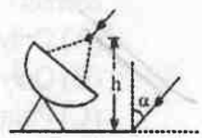
Q.49 A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate with the curved surface downwards. Monochromatic light is incident normally from the top. The observed interference fringes from this combination do not follow one of the following statements.
(A) the fringes are straight and parallel to the length of the piece.
(B) the line of contact of the cylindrical glass piece and the glass plate appears dark.
(C) the fringe spacing increases as we go outwards.
(D) the fringes are formed due to the interference of light rays reflected from the curved surface of the cylindrical piece and the top surface of the glass plate.

Q.50 A circular planar wire loop is dipped in a soap solution and after taking it out, held with its plane vertical in air. Assuming thickness of film at the top very small, as sunlight falls on the soap film, & observer receive reflected light
(A) the top portion appears dark while the first colour to be observed as one moves down is red.
(B) the top portion appears violet while the first colour to be observed as one moves down is indigo.
(C) the top portion appears dark while the first colour to be observed as one move down is violet.
(D) the top portion appears dark while the first colour to be observed as one move down depends on the refractive index of the soap solution.

Q.51 A thin film of thickness t and index of refraction 1.33 coats a glass with index of refraction 1.50. What is the least thickness t that will strongly reflect light with wavelength 600 nm incident normally?
(A) 225 nm (B) 300 nm (C) 400 nm (D) 450 nm

Q.52 It is necessary to coat a glass lens with a non-reflecting layer. If the wavelength of the light in the coating is λ, the best choice is a layer of material having an index of refraction between those of glass and air and a thickness of
(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{2}$ (C) $\frac{3\lambda}{8}$ (D) λ

Q.53 Radio waves coming at $\angle\alpha$ to vertical are recieved by a radar after reflection from a nearby water surface & directly. What should be height of antenna from water surface so that it records a maximum intensity. (wavelength = λ).



(A) $\frac{\lambda}{2\cos\alpha}$ (B) $\frac{\lambda}{2\sin\alpha}$
(C) $\frac{\lambda}{4\sin\alpha}$ (D) $\frac{\lambda}{4\cos\alpha}$

Q.54 In a biprism experiment the distance of source from biprism is 1 m and the distance of screen from biprism is 4 metres. The angle of refraction of biprism is 2×10^{-3} radians. μ of biprism is 1.5 and the wavelength of light used is 6000Å. How many fringes will be seen on the screen?
(A) 4 (B) 5 (C) 3 (D) 6

Q.55 In a biprism experiment using sodium light $\lambda = 6000$ Å an interference pattern is obtained in which 20 fringes occupy 2 cm. On replacing sodium light by another source of wavelength λ_2 without making any other change 30 fringes occupy 2.7 cm on the screen. What is the value of λ_2?
(A) 4500 Å (B) 5400 Å (C) 5600 Å (D) 4200 Å

Q.56 A parallel coherent beam of light falls on fresnel biprism of refractive index μ and angle α. The fringe width on a screen at a distance D from biprism will be (wavelength = λ)
(A) $\frac{\lambda}{2(\mu-1)\alpha}$ (B) $\frac{\lambda D}{2(\mu-1)\alpha}$ (C) $\frac{D}{2(\mu-1)\alpha}$ (D) none

ONE OR MORE THAN ONE OPTION MAY BE CORRECT

Take approx. 3 minutes for answering each question.

Q.1 To observe a stationary interference pattern formed by two light waves, it is not necessary that they must have :

(A) the same frequency (B) same amplitude
(C) a constant phase difference (D) the same intensity

Q.2 A light of wavelength 600nm in air enters a medium of refractive index 1.5. Inside the medium :

(A) its frequency is 5×10^{14} Hz (B) its frequency is 7.5×10^{14} Hz
(C) its wavelength is 400nm (D) its wavelength is 900nm

Q.3 Four monochromatic and coherent sources of light, emitting waves in phase of wavelength λ, are placed at the points $\rightarrow x = 0$, d, 2d and 3d on the x-axis. Then

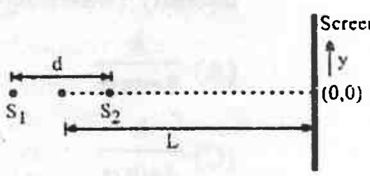
(A) points having $|x| >> d$ appear dark if $d = \lambda/4$
(B) points having $|x| >> d$ appear dark if $d = \lambda/8$
(C) points having $|x| >> d$ appear maximum bright if $d = \lambda/4$
(D) points having $|x| >> d$ appear maximum bright if $d = \lambda/8$

Q.4 In the above question, the intensity of the waves reaching a point P far away on the +x axis from each of the four sources is almost the same, and equal to I_0. Then,

(A) If $d = \lambda/4$, the intensity at P is $4I_0$. (B) If $d = \lambda/6$, the intensity at P is $3I_0$.
(C) If $d = \lambda/2$, the intensity at P is $3I_0$. (D) none of these is true.

Q.5 The figure shows two points source which emit light of wavelength λ in phase with each other and are at a distance $d = 5.5\lambda$ apart along a line which is perpendicular to a large screen at a distance L from the centre of the source. Assume that d is much less than L. Which of the following statement is (are) correct?

(A) Only five bright fringes appear on the screen
(B) Only six bright fringes appear on the screen
(C) Point y = 0 corresponds to bright fringe
(D) Point y = 0 corresponds to dark fringe.



Q.6 White light is used to illuminate two slits in a YDSE. The separation between the slits is d and the screen is at a distance D (D >> d) from the slits. At a point on the screen directly in front of one of the slits, which of the following wavelengths are missing.

(A) $\frac{d^2}{D}$ (B) $\frac{2d^2}{D}$ (C) $\frac{d^2}{3D}$ (D) $\frac{2d^2}{3D}$

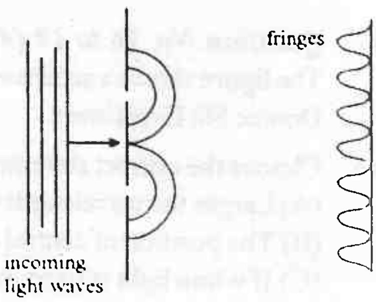
Q.7 In a YDSE apparatus, we use white light then :

(A) the fringe next to the central will be red (B) the central fringe will be white.
(C) the fringe next to the central will be violet (D) there will not be a completely dark fringe.

Q.8 If the source of light used in a Young's Double Slit Experiment is changed from red to blue, then

(A) the fringes will become brighter
(B) consecutive fringes will come closer
(C) the number of maxima formed on the screen increases
(D) the central bright fringe will become a dark fringe.

Q.9 In a Young's double slit experiment, green light is incident on the two slits. The interference pattern is observed on a screen. Which of the following changes would cause the observed fringes to be more closely spaced?
(A) Reducing the separation between the slits
(B) Using blue light instead of green light
(C) Used red light instead of green light
(D) Moving the light source further away from the slits.



Q.10 In a Young's double-slit experiment, let A and B be the two slits. A thin film of thickness t and refractive index μ is placed in front of A. Let β = fringe width. The central maximum will shift :

(A) towards A (B) towards B (C) by $t(\mu - 1)\frac{\beta}{\lambda}$ (D) by $\mu t \frac{\beta}{\lambda}$

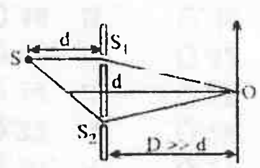
Q.11 In the **previous question**, films of thicknesses t_A and t_B and refractive indices μ_A and μ_B, are placed in front of A and B respectively. If $\mu_A t_A = \mu_B t_B$, the central maximum will :
(A) not shift (B) shift towards A
(C) shift towards B (D) option (B), if $t_B > t_A$; option (C) if $t_B < t_A$

Q.12 In a double slit experiment, instead of taking slits of equal widths, one slit is made twice as wide as the other. Then in the interference pattern :
(A) the intensities of both the maxima and minima increase.
(B) the intensity of the maxima increases and the minima has zero intensity.
(C) the intensity of the maxima decreases and that of minima increases.
(D) the intensity of the maxima decreases and the minima has zero intensity.

Q.13 In a YDSE, if the slits are of unequal width :
(A) fringes will not be formed
(B) the positions of minimum intensity will not be completely dark
(C) bright fringe will not be formed at the centre of the screen.
(D) distance between two consecutive bright fringes will not be equal to the distance between two consecutive dark fringes.

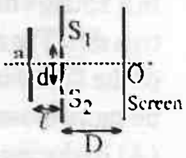
Q.14 If one of the slits of a standard YDSE apparatus is covered by a thin parallel sided glass slab so that it transmit only one half of the light intensity of the other, then :
(A) the fringe pattern will get shifted towards the covered slit.
(B) the fringe pattern will get shifted away from the covered slit.
(C) the bright fringes will be less bright and the dark ones will be more bright.
(D) the fringe width will remain unchanged.

Q.15 To make the central fringe at the centre O, a mica sheet of refractive index 1.5 is introduced. Choose the correct statements (s).
(A) The thickness of sheet is $2(\sqrt{2}-1)d$ infront of S_1.
(B) The thickness of sheet is $(\sqrt{2}-1)d$ infront of S_2.
(C) The thickness of sheet is $2\sqrt{2}d$ infront of S_1.
(D) The thickness of sheet is $(2\sqrt{2}-1)d$ infront of S_1.



Question No. 16 to 19 (4 questions)

The figure shows a schematic diagram showing the arrangement of Young's Double Slit Experiment



Q.16 Choose the correct statement(s) related to the wavelength of light used
(A) Larger the wavelength of light larger the fringe width
(B) The position of central maxima depends on the wavelength of light used
(C) If white light is used in YDSE, then the violet colour forms its first maxima closest to the central maxima
(D) The central maxima of all the wavelengths coincide

Q.17 If the distance D is varied, then choose the correct statement(s)
(A) The angular fringe width does not change
(B) The fringe width changes in direct proportion
(C) The change in fringe width is same for all wavelengths
(D) The position of central maxima remains unchanged

Q.18 If the distance d is varied, then identify the correct statement
(A) The angular width does not change
(B) The fringe width changes in inverse proportion
(C) The positions of all maxima change
(D) The positions of all minima change

Q.19 Identify the correct statement(s) if the source slit S moved closer to S_1S_2, i.e. the distance ℓ decreases
(A) nothing happens to fringe pattern
(B) fringe pattern may gets less sharp
(C) fringe width remains unchanged
(D) fringe pattern may dissapear

Answer Key

ONLY ONE OPTION IS CORRECT.

Q.1 A	Q.2 C	Q.3 C	Q.4 C	Q.5 C	Q.6 D	Q.7 A
Q.8 A	Q.9 D	Q.10 D	Q.11 B	Q.12 D	Q.13 B	Q.14 C
Q.15 B	Q.16 D	Q.17 B	Q.18 C	Q.19 B	Q.20 A	Q.21 C
Q.22 D	Q.23 C	Q.24 D	Q.25 A	Q.26 A	Q.27 A	Q.28 A
Q.29 C	Q.30 C	Q.31 A	Q.32 C	Q.33 C	Q.34 D	Q.35 A
Q.36 D	Q.37 A	Q.38 A	Q.39 D	Q.40 A	Q.41 C	Q.42 C
Q.43 A	Q.44 C	Q.45 B	Q.46 A	Q.47 C	Q.48 B	Q.49 C
Q.50 C	Q.51 A	Q.52 A	Q.53 D	Q.54 B	Q.55 B	Q.56 A

ONE OR MORE THAN ONE OPTION MAY BE CORRECT.

Q.1 B,D	Q.2 A,C	Q.3 A	Q.4 B
Q.5 A,D	Q.6 A,C	Q.7 B,C,D	Q.8 B,C
Q.9 B	Q.10 A,C	Q.11 D	Q.12 A
Q.13 B	Q.14 A,C,D	Q.15 A	Q.16 A,C,D
Q.17 A,B,D	Q.18 B,D	Q.19 B,C,D	